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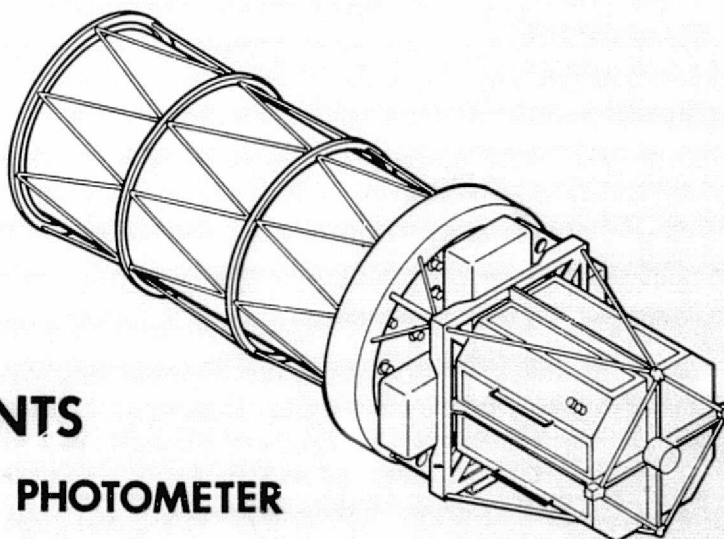
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SPACE TELESCOPE
PHASE B DEFINITION STUDY
FINAL REPORT

VOLUME II-A
SCIENCE INSTRUMENTS
HIGH SPEED POINT/AREA PHOTOMETER



MAY 1976

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

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FOREWORD

This Final Report documents and summarizes (per the requirements of MSFC Procurement Document 395-MA-06) the analysis and preliminary design of a High Speed Point/Area Photometer for the Space Telescope. This Science Instrument is designed for an axial module position in the Focal Plane Assembly. The design was accomplished as part of the LST Phase B Definition Study, Optical Telescope Assembly/Science Instruments for NASA, Marshall Space Flight Center under Contract NAS8-29948. With the exception of Paragraphs 4.1, 4.2, 4.3 and 8.3, which were completed by Perkin-Elmer, the work was performed by Ball Brothers Research Corporation, Boulder, Colorado, for Perkin-Elmer Corporation, Optical Technology Division, under P-E Contract 25140-PT. Technical direction for the Science Instrument design was provided by Perkin-Elmer in accordance with instrument requirements established by the Goddard Space Flight Center.

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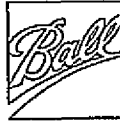
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SUMMARY

The primary purpose of this study was to derive a preliminary design for a High Speed Point/Area Photometer (HSP/AP) scientific instrument for the Space Telescope (ST). The instrument is required to be rugged, simple, reliable, and versatile and capable of precision photometric measurements of the ultraviolet and visible spectrum with high time resolution. The instrument must possess capability for spatial resolution to the diffraction limit of the telescope, temporal resolution to fractional milliseconds, have photometric precision of one percent or better and operational capability over a wide range of observing programs.

Optically speaking, the HSP/AP instrument is a dual power relay capable of reimaging the field of view without magnification to any one of three detector positions, and also at 4X magnification to the area detector. The data collected can be from either point sources or celestial fields of small angular size. Three photon counting detectors are used, an Intensified Charge Coupled Device (ICCD) for area photometry, and two Image Dissector Sensors (IDS) for point source photometry.

If it should be desired to revive the polarimetry function of the instrument, which was considered initially in the study, further effort is recommended into investigation of the best technique to make an optically contacted multiple Rochon prism from MgF_2 , and to figure a focus adjusting surface on one end. Further, the calculation of the achromatic retarders should be performed with limits set by actual detector response limits. In this way a higher degree of polarimetric precision can be achieved in the visible spectrum.

Four mechanisms are utilized to provide for selection of the aperture size, the filters and the detector. All mechanisms



have simple rotary motions which enable long-life and high reliability. The mechanism designs are based on space qualified concepts. In addition, each mechanism can be provided with a fail-safe device and position.

The electronic system described provides the necessary instrument controls, data storage, and processing support to realize the scientific objectives. Because of the complex routines required for observation, a dedicated electronic control system is necessary. Therefore a micro-processor commanded by a central computer is included for system control and data processing. The HSP/AP interface is with the scientific instruments command and data handling system.

The design of the High Speed Point/Area Photometer presented in this report is optically simple. The optical surfaces are all planes with the exception of the surfaces of two elements and these two remain fixed in position. All the image forming, magnifying and aberration correction functions are handled by these two optical elements. All switching optics are flat mirrors.

A unit power relay forms a corrected image for either of the point detectors or the $f/24$ area detector. A four power magnifier enlarges this image and displays it on the same area detector for $f/96$ area photometry.

Provision is made for a variety of entrance aperture sizes and shapes. Spectral selection is accomplished by rotating filters mounted on wheels into the beam. Two filter selectors are in series. These filter selector wheels contain bandpass, high and low pass and blocking filters permitting use singularly or in the series pairs.



With the optical design defined, all point sources anywhere in the field of view are imaged entirely within the area of a single pixel.

The selection of an image dissector for the point detection function provides backup scanning capability in the event of area detector malfunction as well as effective limitation of photocathode area to minimize extraneous noise problems.

In accordance with the instrument study directives, no provision is made for internal calibration. This function will be performed by observing "standard" celestial sources and/or extended objects of "uniform" brightness.

The mechanical/optical layout of the instrument included consideration of optical, thermal, structural, power, and modularity requirements. Components are placed to allow thermal isolation and heat dumping from the major heat producers. Accessibility is provided for installation and alignment of the optics sub-assemblies. The detectors and the memory are placed in the aft end of the instrument container for easy access, thermal isolation, and replacement if necessary. Also the design impact of the substitution of other configuration detectors is minimized.

The performance criteria set forth in the "Final Instrument Definition", June 1974, and the "LST Scientific Instruments Requirements for Preliminary Design", as revised 15 April 1975, can be achieved in a straightforward, reliable instrument as defined by this study. Sufficient design flexibility is also included to accommodate possible future desired expansion of performance capability.



ABBREVIATIONS

A/D	Analog to Digital
FGS	Fine Guidance Sensor
FID	Final Instrument Definition
FOV	Field of View
FPA	Focal Plane Assembly
FPS	Focal Plane Structure
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HSP/AP	High Speed Point/Area Photometer
HVPS	High Voltage Power Supply
ICCD	Intensified Charge Coupled Device
IDS	Image Dissector Sensor
LVPS	Low Voltage Power Supply
OTA	Optical Telescope Assembly
RAM	Random Access Memory
SI	Scientific Instruments
SSM	Support System Module
ST	Space Telescope
TBD	To be Determined
TSM	Thermal Structural Model
UV	Ultraviolet



Section 1 INTRODUCTION

The High Speed Point/Area Photometer is designed to extend photometric capability beyond the wavelength limits and temporal and spatial resolution restrictions imposed by the earth's atmosphere. For this purpose an instrument design concept of mechanical and optical simplicity, yet still compatible with the ST scientific instrument versatility requirements is provided. The guidelines and requirements for the instrument design were established by the "Final Instrument Definition" dated June 1974, as modified and interpreted by the "LST Scientific Instrument Requirements for Preliminary Design", revision dated 15 April 1975.



Section 2

OBJECTIVES AND REQUIREMENTS

The purpose of the High Speed Point/Area Photometer (HSP/AP) is to provide precision photometric measurements with high time resolution in the UV and visible wavelengths. The instrument should be capable of spatial resolution to the diffraction limit of the telescope, temporal resolution to fractional milliseconds and photometric precision of one percent or better. As a space telescope instrument it must be rugged, simple, reliable and versatile.

2.1 SCIENTIFIC OBJECTIVES

The objective of putting a photometer into space is to extend the photometric function in the UV and visible wavelengths beyond the limits imposed on ground based instruments by the atmosphere. To this end the spectral range (115 to 650 nm) extends beyond the ozone layer cutoff on the shortwave end, and the spatial resolution and temporal resolution both extend beyond the constraints of atmospheric scintillation.

Thus, the Ultraviolet-Blue-Visible (UBV) classification of stars can be extended into the vacuum ultraviolet, the rapid variations of pulsars and neutron stars can be analyzed and photometric measurements of close binary systems can be performed.

2.2 PHOTOMETER REQUIREMENTS

The requirements tabulated in Table II-1 are taken from the Final Instrument Definition (FID), June 1975, as modified by the "LST Scientific Instruments Requirements for Preliminary Design" document, revised 15 April 1975.



Table II-1
HSP/AP REQUIREMENTS/CAPABILITIES

Wavelength Range: 115 to 650 nm

Wavelength Resolution: as defined by filters (see Table III-2 and Figure 3-5)

Number of filters: Two wheels with 8 filter positions each, so arranged that those that are to be used in series are on separate wheels. Each wheel also contains an open and dark position (see Table III-2).

Point Detector: Two photomultipliers or Image Dissector Sensors with effective photocathode diameter ≤ 1 mm. One with CsI photocathode on MgF_2 window uncooled, the second with bi-alkali photocathode on MgF_2 window, uncooled.

Area Detector: ICCD with bi-alkali cathode on MgF_2 window, cooled to 230°K. For analog operation: format, 100 x 160 pixels in 3 x 4.5 mm.

Field of View: A) Point detector: variable in steps from 0.14 arc second to 3.6 arc second. Variable (defined by selected aperture), with center maintained to ± 0.05 arc second during an exposure.
B) Area detector: 10.7 x 16.1 sec (f/24) and 2.7 x 4 arc sec (f/96).

Angular Resolution: Area detector: near diffraction limit.

Exposure Time: Accuracy: better than $\pm 0.1\%$.
Duration: 1 msec to 5 hours.

Number of Apertures: 10, including dark position

Photometric Accuracy: Area detector: 1%. Point detector: 0.1 to 1%

Brightness Range: Maximum: 7.5 Mag with less than 10% coincidence loss
Minimum: Noise limit

Acquisition: Verification using area detector or image dissector as post aperture camera.

Calibration: Using external sources.



Section 3 DESIGN CONCEPTS

3.1 OPTICAL DESIGN

Optically speaking, the High Speed Point/Area Photometer is a dual power relay capable of reimaging the field-of-view without magnification to any one of three detector positions, and at 4X magnification to one of the three. Figure 3-1 shows the optical geometry of the instrument.

The relay mirror is a toroidal mirror with radii of 500 to 508 mm respectively. Correction is necessary to compensate for the astigmatism of the telescope image in the photometer off-axis aperture position and the tilt of the internal photometer relay mirror. The adequacy of the correction is borne out in the spot diagram presented in Figure 3-2.⁽¹⁾ Without the intervention of any of the mirrors in the line of sight, the relayed image would appear at the end of the dotted line at the point marked virtual image (Figure 3-1). The switching mirror turret contains three plane mirrors and one clear aperture. A given mirror directs the unmagnified image to one of the three detectors. In the fourth position (clear), the rays continue through until they encounter the hyperboloid mirror. This mirror acts like the secondary in a Cassegrain system and magnifies the image by a factor of four as it reflects to the area detector (ICCD).

The imagery is of essentially the same quality at unit power and at 4 power. The area detector is oriented nearly normal (within the configuration constraints) to the unit power bundle

⁽¹⁾ Based on expected off-axis image of the OTA as defined by Perkin-Elmer. See paragraph 4.1.

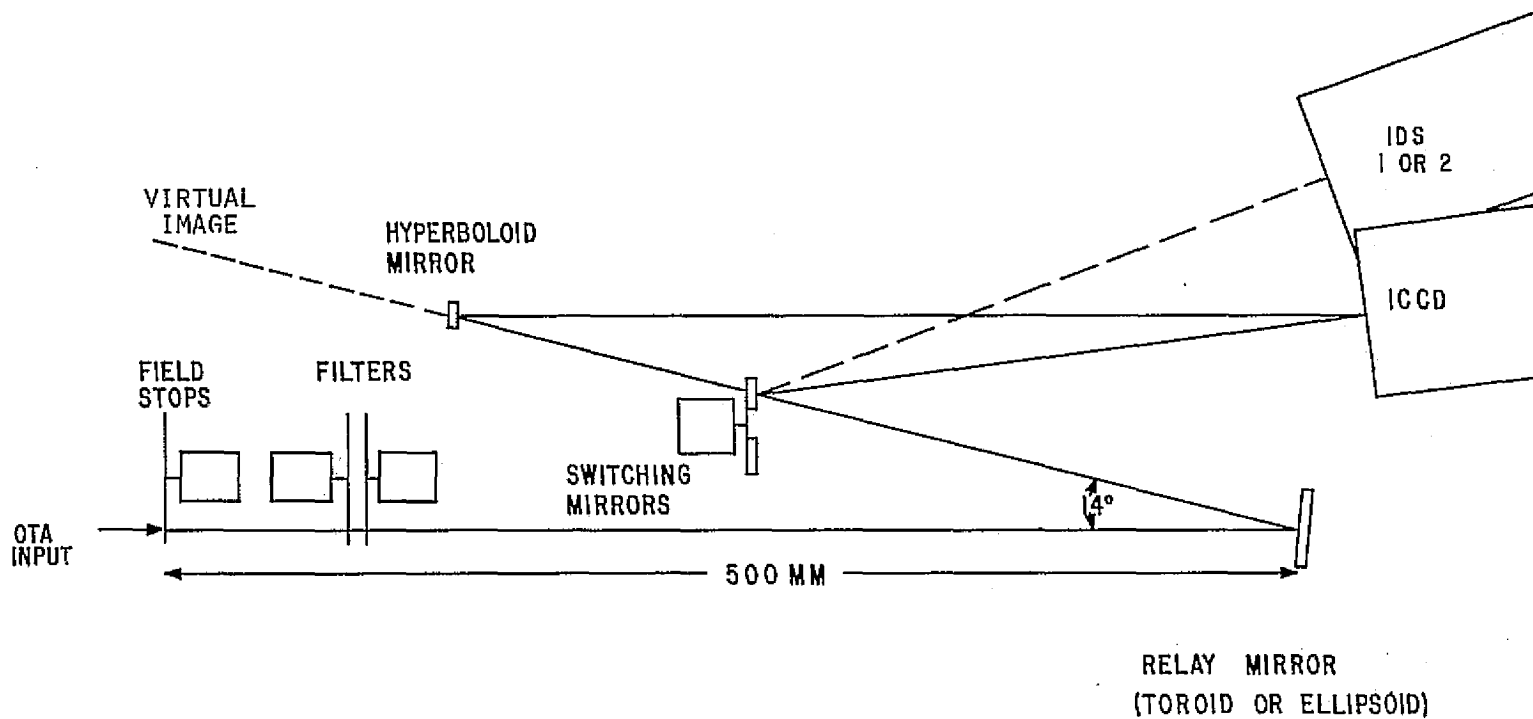


Figure 3-1 High Speed Point/Area Photometer Optical Layout



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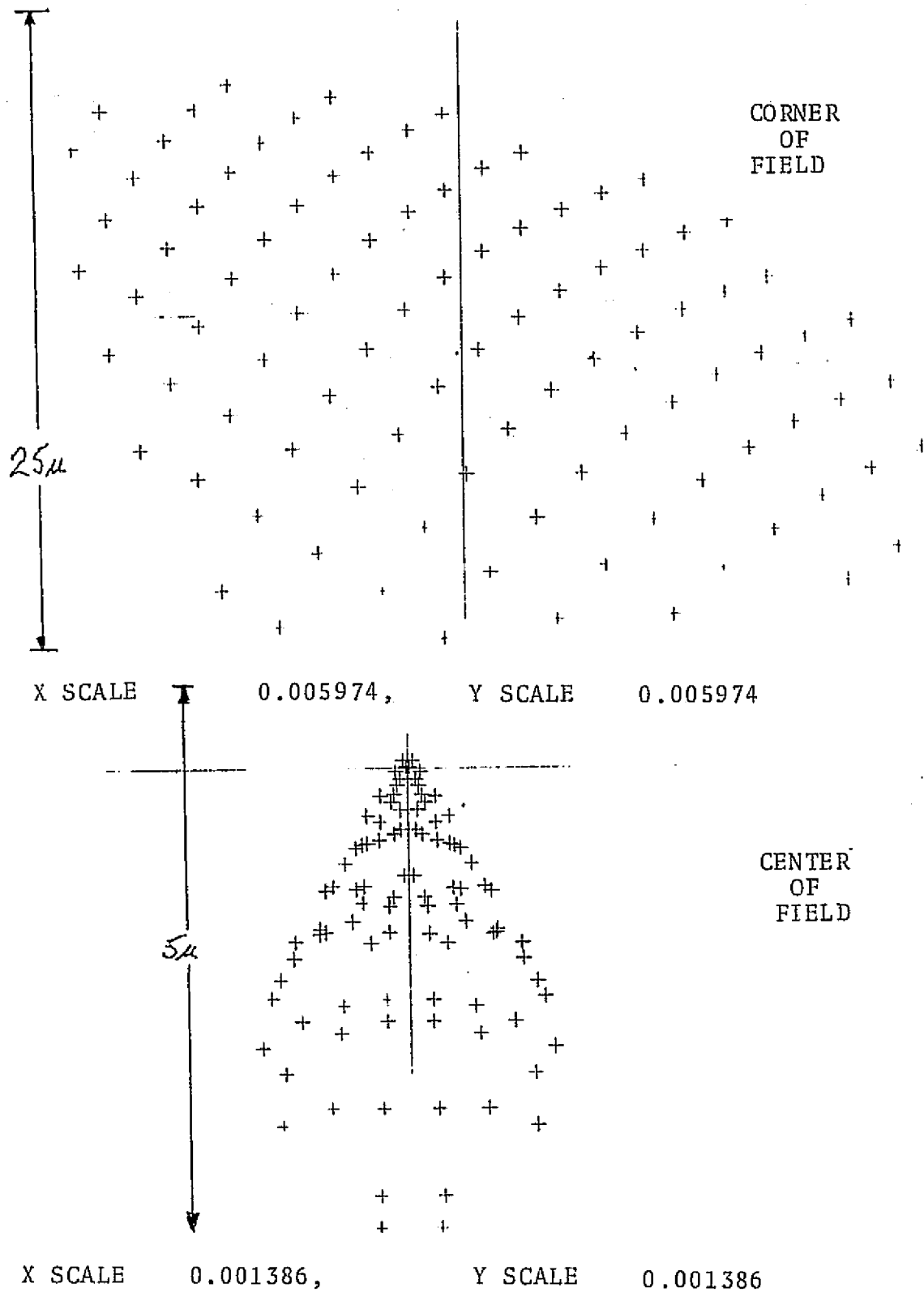
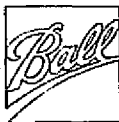


Figure 3-2 Spot Diagram, Unit Power



to place the detector focus in an acceptable focus plane. The $f/24$ optics are more sensitive to defocus than the $f/96$ system.

The quality of the imagery at $f/96$ is shown by the spot diagram in Figure 3-3.⁽¹⁾ As in the case of the unit power image, the spot in the middle of the picture is less than one quarter of a pixel in size but at the corner of the field, the aberrations almost cause it to fill a $25\text{ }\mu\text{m}$ pixel. Thus, the image is kept smaller than a picture element throughout both the $f/96$ and $f/24$ field and is virtually diffraction limited in the middle half of the field.

3.1.1 Field Stops

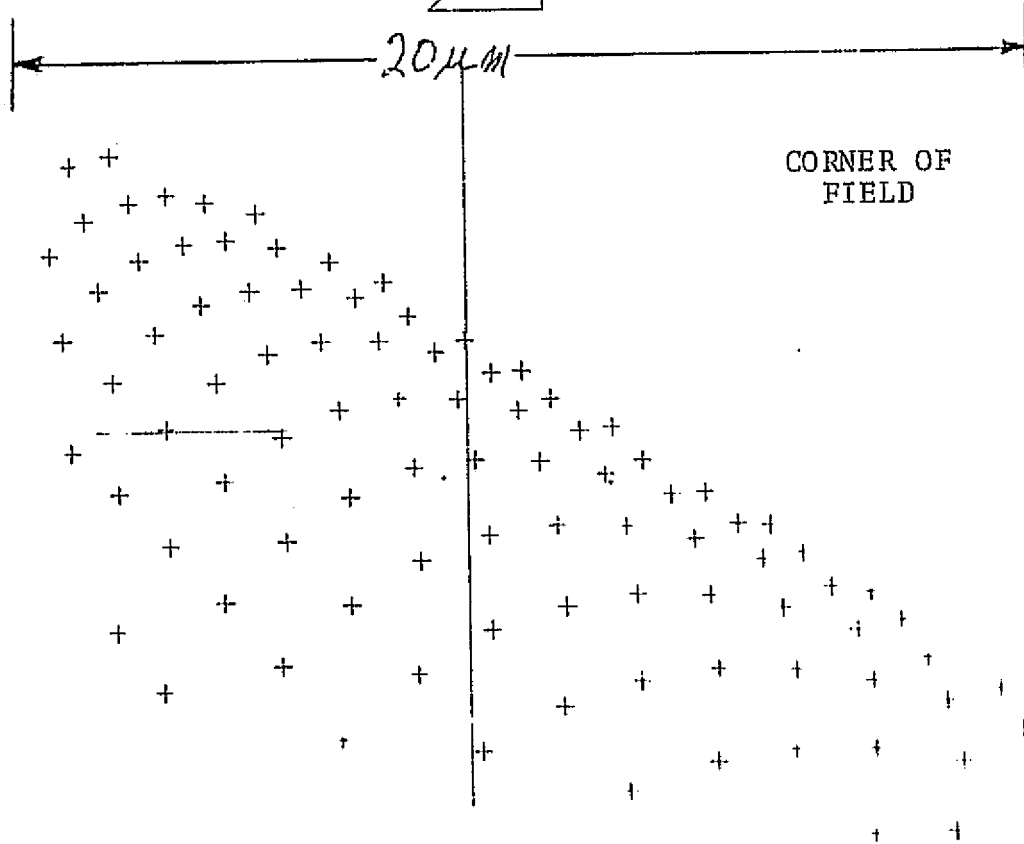
A wheel containing a graduated series of 9 field stops plus an opaque position is placed at the telescope focal surface. The smallest stop is 40 micrometers in diameter, nominally twice the diameter of an Airy disc. The stops increase in size by a factor of two until the last one is just smaller than the 1 millimeter effective aperture of the Image Dissector Sensor. Next is a square aperture 1.2 mm on a side which serves as the largest stop for the point detectors and for the area detector operating at $f/96$. Then follows a $3 \times 4.5\text{ mm}$ stop to match the $f/24$ area detector and a pair of orthogonal slits, each $20\text{ }\mu\text{m}$ wide by 1 mm long. The last position is opaque for dark current measurements and to serve as protection against contamination during instrument down time. Table III-1 summarizes the field stops wheel positions and sizes.

3.1.2 Filters

It is recognized that the filters for the photometer, or at least some of them, are subject to change, depending on the availability of improved detectors and on developments in observational astronomy prior to flight hardware commitment. Table III-2 lists a suitable set of filters that satisfy the requirements of the FID document.

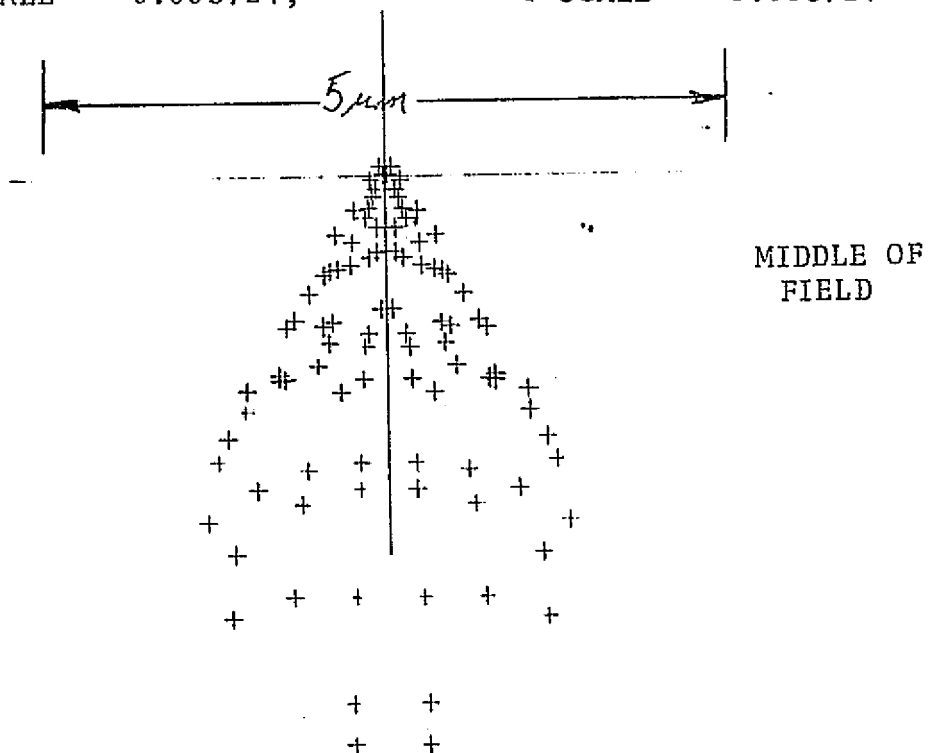


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X SCALE 0.003724,

Y SCALE 0.003724



X SCALE 0.001390,

Y SCALE 0.001390

Figure 3-3 Spot Diagrams, Four Power



Table III-1
HIGH SPEED POINT/AREA PHOTOMETER
FIELD STOP COMPLEMENT

1. 40 μm (2 Airy disc diameters)
2. 80 μm (diameter)
3. 160 μm (diameter)
4. 320 μm (diameter)
5. 640 μm (diameter)
6. 1.2 mm square
7. 3 x 4.5 mm (full ICCD format)
8. 20 x 1000 μm horizontal slit
9. 20 x 1000 μm vertical slit
10. Dark

Some of the suggested filters directly relating to the extended red response have been replaced by other filters providing better observing efficiency. Figure 3-4 illustrates the excellent bandpass characteristics of some ultraviolet transmitting materials when used in conjunction with a CsI photocathode. A UV grade quartz filter becomes an almost perfect high efficiency filter for the U_4 band. U_5 can be measured by subtracting the flux through a quartz filter from the flux through CaF_2 . This approach provides a higher precision reading in less observing time than by using metal dielectric filters.

Figure 3-5 might suggest that there is no need for a red leak filter because the quantum efficiency curve for bi-alkali cathode falls off before the secondary peaks of the U or B filters start their rise. However, the curves do not accurately portray the long low wings of the transmission curves which can integrate out to a significant amount of spurious signal. Therefore, a cut-off filter, either dielectric or absorption type is included for this purpose.



Table III-2
HIGH SPEED POINT/AREA PHOTOMETER
FILTER COMPLEMENT

WHEEL 1

<u>Position</u>	<u>Name</u>	<u>Range</u>	<u>Description</u>
1	SiO ₂	160-660	Doubles for U ₄ when used with CsI
2	CaF ₂	125-660	Redundant-also double for U ₅ by subtracting SiO ₂
3	U ₃	210-280	Acton two cavity metal dielectric
4	U ₂	270-350	Schott #wg-280 - Use with filter 3 on wheel 2
5	U	395	Corning #9863 + Schott #gg-305
6	B	437	Corning #5030 + Schott #gg-385
7	UR	125-365	CaF ₂ - use with filter 4 on wheel 2
8	Spare		
9	Open		
10	Opaque Position (optional use)		

WHEEL 2

<u>Position</u>	<u>Name</u>	<u>Range</u>	<u>Description</u>
1	U ₅	125-160	Acton 2 cavity on CaF ₂ substrate Metal Dielectric
2	U ₄	160-220	Acton# 73-J Metal Dielectric
3	SW-350	-350	Short wave pass dielectric
4	SW-365	-365	" " " "
5	V ₁	544	Corning #3384
6	VR	380-660	Schott gg-385
7	CU	300-540	CuSO ₄ or SW-540
8	RL	470-	Schott - gg-475
9	Open		
10	Opaque Position (optional use)		

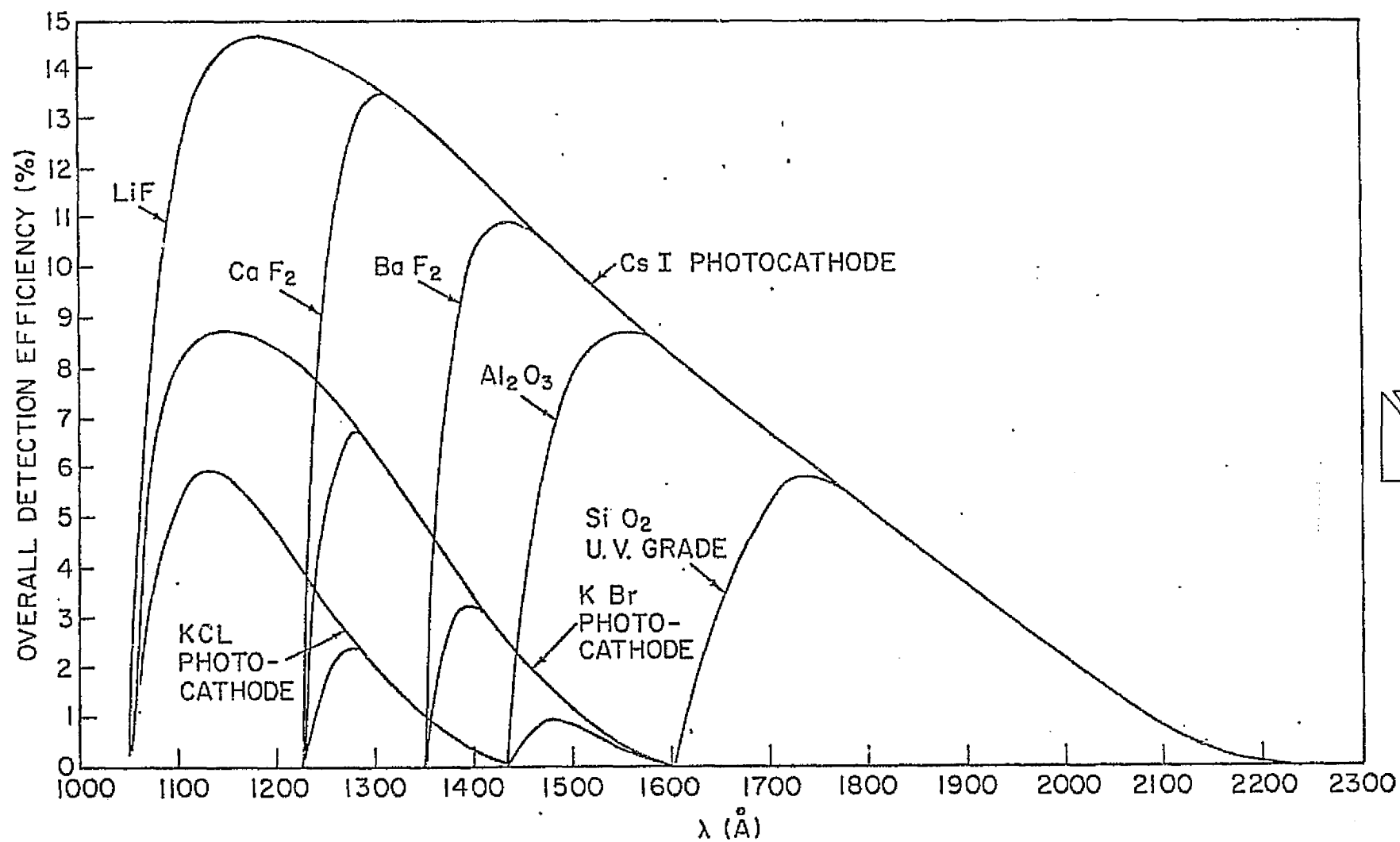


Figure 3-4 Spectral Characteristics of Various Photocathodes

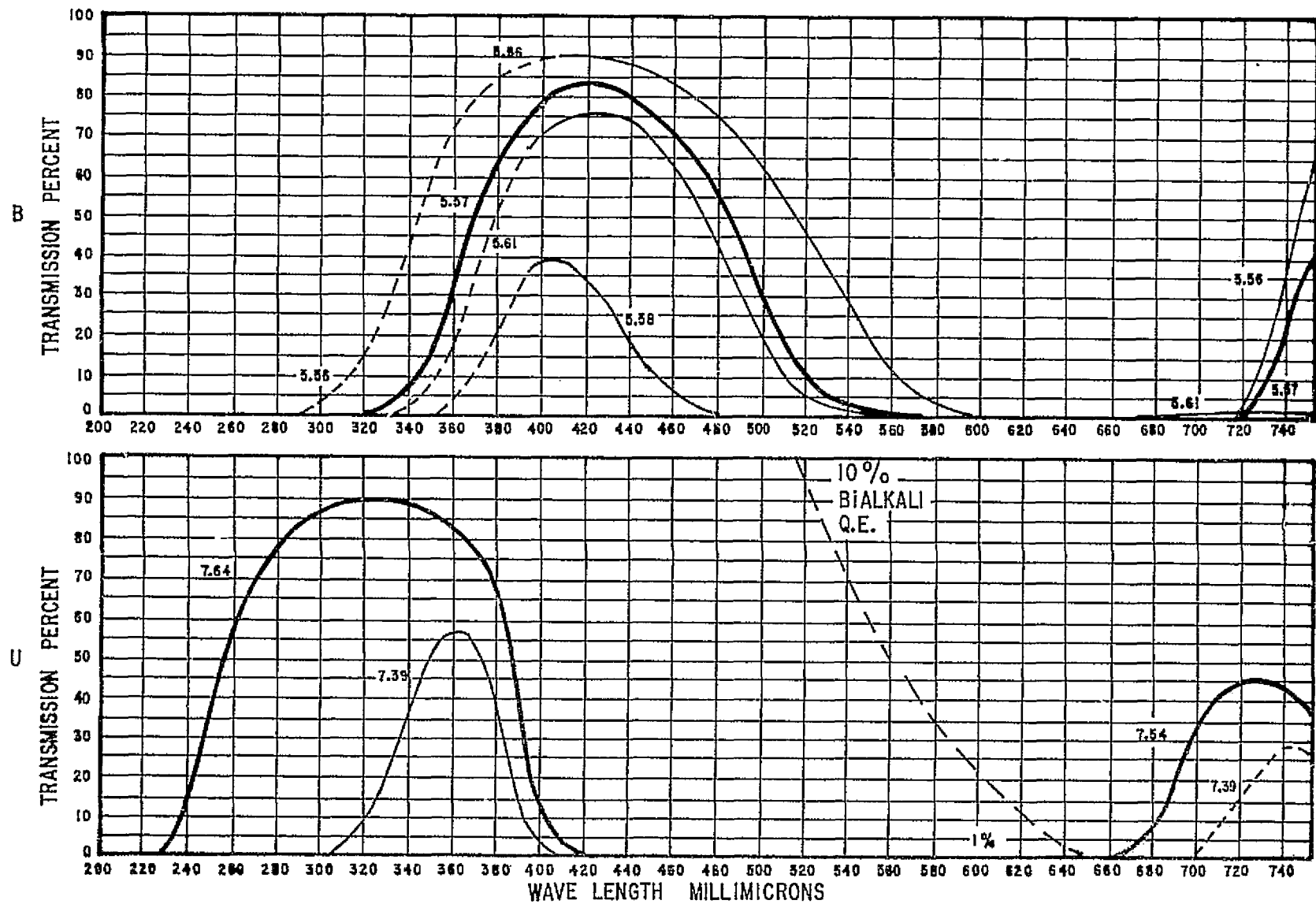


Figure 3-5 B and U Filters with Bialkali Cutoff



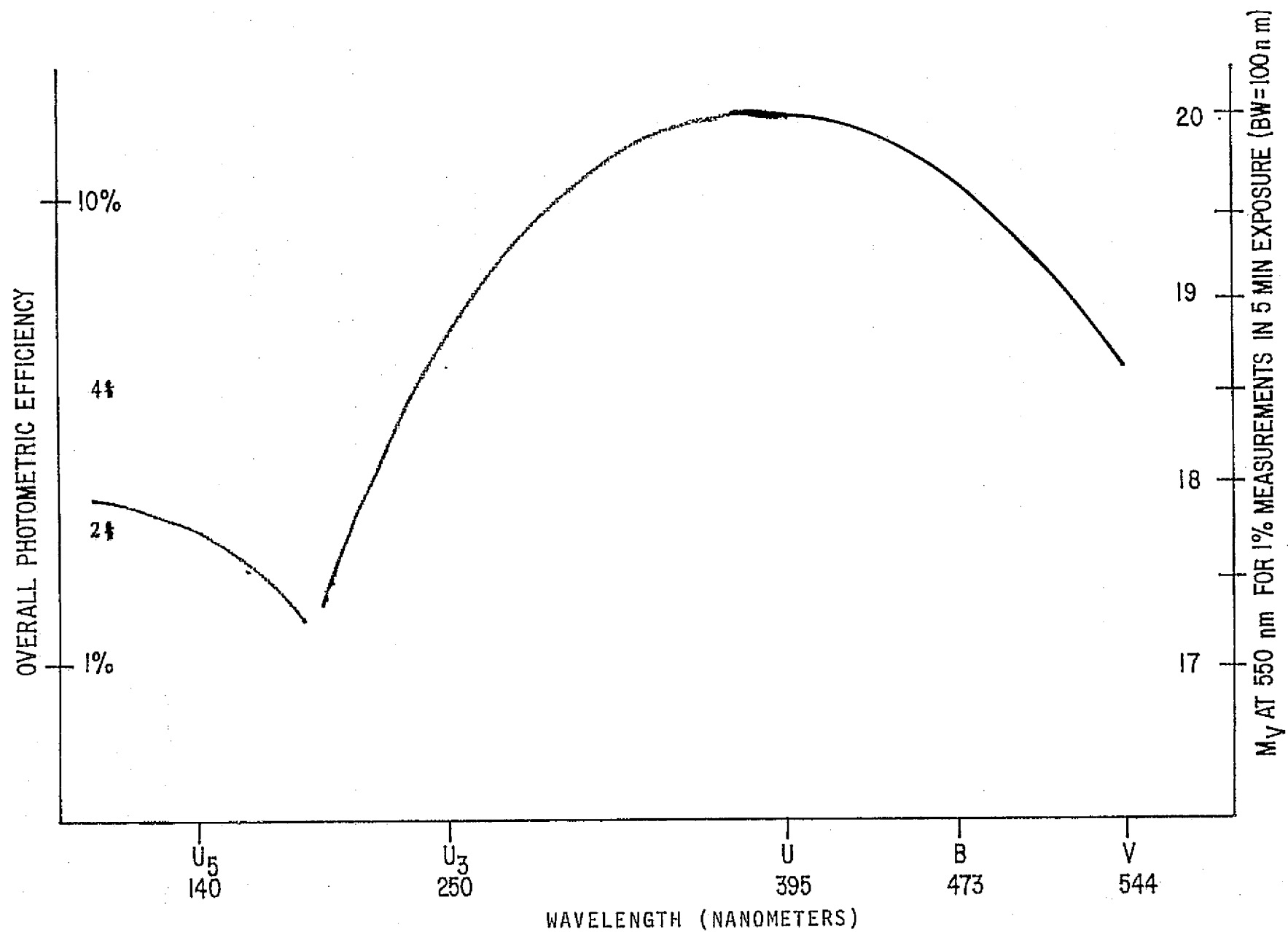
The location of the filters on the two wheels has been changed to satisfy another criterion. Besides the requirement for the red leak filter to be on the opposite wheel from the U and B filters, cut-on filters should be on one wheel and cut-off filters on the other to permit the use of the combination as bandpass filters.

Alternate filter choices were included to help alleviate the problems of the low throughput in the CsI spectral range. This is caused in part by the lower quantum efficiency of this photocathode and the reduced reflectance of the aluminum mirrors, but mostly because of the low peak transmission and narrow passband of the metal dielectric filters. The spectral separation can be achieved with much greater efficiency using the cut-on edge of CaF_2 and SiO_2 as indicated in this design.

3.1.3 Performance

The geometrical performance capability of the optical system was shown in the spot diagrams presented earlier in Figures 3-2 and 3-3. The photometric precision is determined by the photon counting statistics. For 1% precision, there should be 10,000 photon events recorded and for 0.1%, the number is increased to a million. The photometric precision desired is between these two values. Figure 3-6, in addition to indicating the efficiency of the photometer at several of its wavelengths, also shows the corresponding visual magnitude threshold for 1% photometry in a five minute exposure. Photometry of 0.1% would drop the threshold by 5 magnitudes from about 19 to about 14. Table III-3 lists some of the key points on the curves.

The exposure timing on which the photometric measurements are also based is controlled by electronically gating the detectors.



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Figure 3-6 HSP/AP Photometric Efficiency



Calibration is performed against known standard celestial sources. As directed, no provisions are included for calibration using internal sources.

Table III-3
HSP/AP THROUGHPUT

FILTER	U _s	U ₃	U	B	V
WAVELENGTH (nm)	140	250	395	473	544
TELESCOPE	.71	.71	.82	.84	.84
INTERNAL-MIRRORS	.71	.71	.82	.84	.84
FILTER	.23	.38	.85	.80	.85
DETECTOR	.16	.24	.27	.18	.07
PRODUCT	.019	.046	.154	.102	.042
EFFECTIVE BW (nm)	30	50	85	100	120

3.1.4 Polarimetry

Notes on implications of restoring polarimetric capability.

3.1.4.1 Optical Implications

There are no optical problems in accommodating the polarimetry function. The MgF₂ multiple Rochon prisms, while unproven, are an extension of current technology. Retardation plates as needed are readily available. The restricted wavelength band to be covered by the achromatic wavelengths will make them even more precise than specified in the FID document. The polarization calibration prism could take the spot in the field stop wheel currently occupied by the largest circular aperture, or one of the other aperture positions.



Use of the ICCD area detector for polarization measurements would require enlarging the analyzer prism by one additional millimeter for f/96 and an additional 4.5 millimeters for f/24 operation. It would be preferable to confine polarization measurements to the point detectors only.

3.1.4.2 Mechanical Implications

For proper operation, the retarder wheel and the analyzer prism should be placed between the field stop and the filter wheel. The easiest way to accomplish this would be to combine the filters on one wheel and place that wheel immediately adjacent to the support for the hyperboloid, then replace the other filter wheel with a 20 position retarder wheel and insert the analyzer prism between them. If this is not acceptable, the two filter wheels can be made more compact and assembled in a staggered fashion so that the motors and wheels overlap. This would leave room to insert the analyzer wheel in the space thus salvaged. In either case, additional mechanisms are required for the retarder wheel and analyzer wheel. This obviously increases the cost and complexity of the instrument. (Note, these concepts were described at the April, 1975 conceptual design review and are illustrated in Perkin-Elmer/BERC Report No. 11880 dated 1 April 1974.)

3.2 DETECTORS

Three detectors are used in the HSP/AP; one area detector and two point detectors. The area detector is an Intensified Charge Coupled Device (ICCD) in which an array of 100 x 160 silicon diodes is placed at the electron image plane of an image intensifier. The photocathode is bi-alkali on a MgF₂ window providing sensitivity between 115 and 650 nanometers. The format of 3 x 4.5 millimeters provides a field of view of 10.7 x 16.1 seconds of



arc at $f/24$ and 2.7×4 seconds at $f/96$. The detector is capable of operating in the photon counting mode with up to 16 events being counted in each readout cycle, or of operating in an analog mode for observing bright objects.

The linear resolution of the detector is 15 line pairs per millimeter, corresponding to a spatial resolution of 0.06 seconds of arc at $f/96$.

The point detectors are Image Dissector Sensors (IDS), ITT type number F-4012. These are to be provided with a MgF_2 face plate and a round electron image aperture of 1 millimeter diameter. A CsI photocathode is used for the shorter wavelength and bi-alkali for the longer wavelength. One of the advantages of the Image Dissector Sensor is that the final size of the aperture can be selected when final system characteristics are evaluated. While a nominal size of one mm is specified now, consideration of cathode generated noise may at a later time, dictate a smaller effective cathode. On the other hand, the desire for a range of field stop sizes indicates that the aperture will most likely approach one millimeter.

A question has been brought up about the scanning function associated with an Image Dissector Sensor. As long as this sensor has been selected as the point detector, the provision of scanning coils was included in the concept. This would permit the use of the point detector as a backup to the area detector, at least in its acquisition function. There are just grounds for having reservations regarding the suitability of this Image Dissector Sensor as a high acuity area detector because of the large size of the instantaneous field of view relative to the telescope diffraction limit. However, a tracking logic that takes the aperture size into account permits its use for pointing error detection.



3.3 MECHANICAL CONCEPT

Structurally, the photometer consists of a "V"-shaped optical bench, shown end-on in Figure 3-7, which hard mounts to the instrument container and focal plane structure. The optical components and subassemblies are fixed to this optical bench. The detectors are mounted on an end plate that forms the back support for the bench. A shelf above the bench and thermally insulated from the bench carries the electronic components, power supplies, memories, processing and control circuits. The boxes are located where short leads to both the instrument and the SI container cold sink, thereby minimizing thermal inputs to the optical bench.

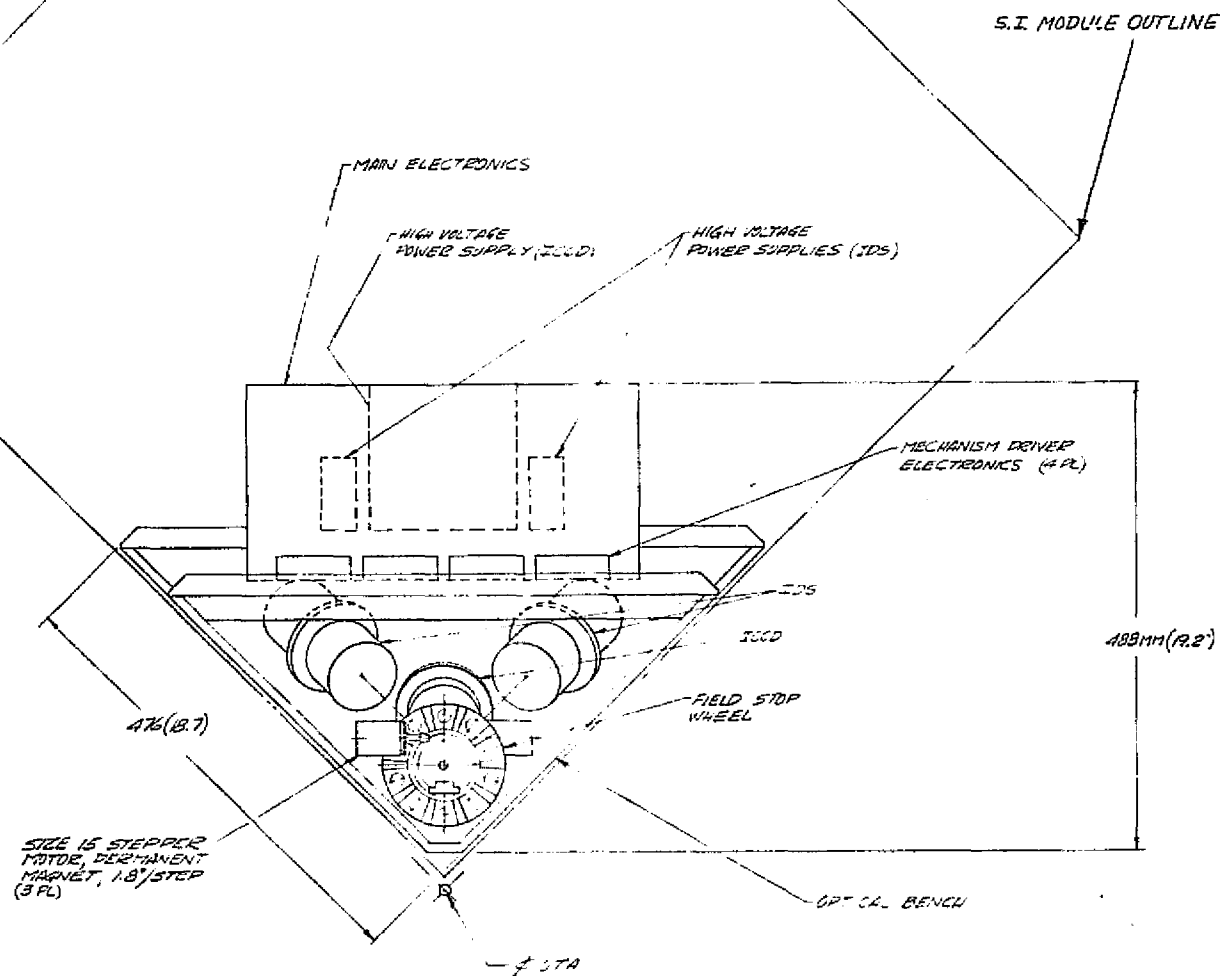
The mechanisms in the photometer consist of four straightforward rotary devices. The aperture wheel and the two filter wheels turn on duplex ball bearings and are driven by stepper motors through high reduction spiroid gears. Proper indexing is assured through the magnetic detent of the stepper motor and the 120/1 gear reduction. Wheel position is identified by an encoder. The fourth mechanism is a four position mirror selector. This is mounted directly to a stepper motor shaft. A counter weight is provided to maintain a balanced condition. The mechanisms arrangement is shown in Figure 3-8.

For simplicity fail-safe mechanisms are not included in the basic instrument concept. The type of mechanisms defined for the photometer have been space qualified and flown on many missions with high reliability. However, if fail-safe mechanisms are deemed necessary then the following approach is a prime candidate.

With the system described, if any of the drive mechanisms become inoperable because of mechanical failure or an electrical control system failure, the inoperable wheel can be independently commanded to a pre-selected position by decoupling it from the

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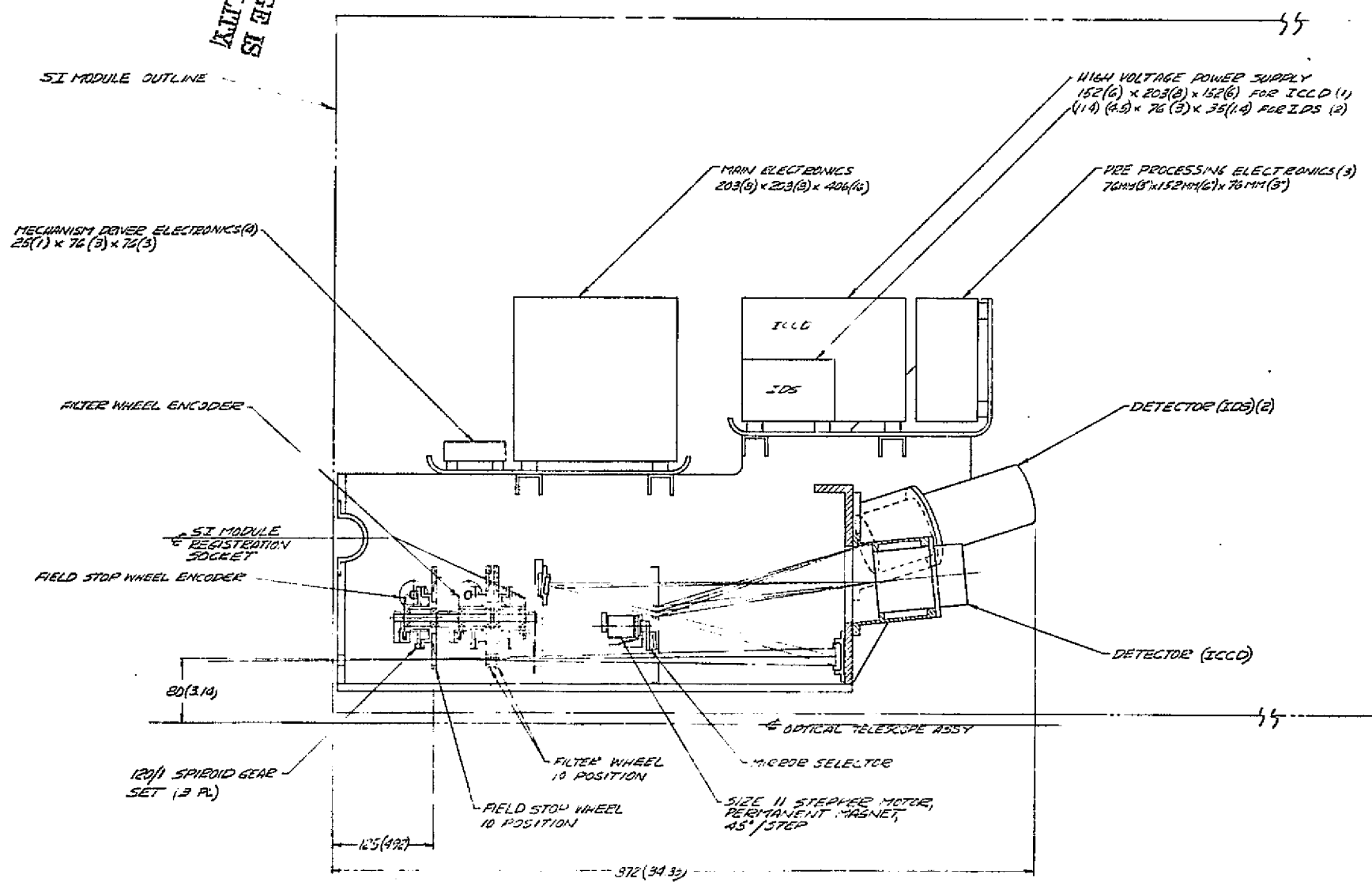


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Figure 3-7 High Speed Point/Area Photometer Layout for ST (End View)

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F76-08

Figure 3-8 High Speed Point/Area Photometer Layout for ST



drive system. In normal operation the wheel is mechanically coupled to the drive gear by a pawl carried in this case on a wheel shown in Figure 3-9. The pawl has a ball end which engages a close fitting slot in the gear hub. Both the ball and the slot are hardened steel. The center of the ball is located so that the coupling force exerted by the torsion spring produces a slight inward radial force on the ball. This helps to keep the pawl engagement locked during normal operation. The pawl is in the form of a bell crank and is suspended on a post on the slit wheel. Ball bearings keep the torsional friction to a minimum. This permits the use of a pawl engagement spring with a light force, and increases the reliability of the fail-safe mechanism.

The fail-safe action is implemented by energizing a solenoid connected to the bell crank that disengages the pawl. The slit wheel, when uncoupled from the drive gear, is driven by the torsion spring against a mechanical stop at one of the slit positions. The torsion spring has more than 360 degrees of pre-load so that it can drive against the stop from any failed position.

If the problem that caused the failure is alleviated, for instance an intermittent problem in the motor driver electronics, the motor can be turned on and has ample torque to wind up the torsion spring while driving the gear around to where the pawl will again engage. The fail safe mechanism is thus resettable for resumption of normal operation. All bearings, gear teeth, pawl slot, and ball are lubricated with BBRC Vac-Kote dry lubricant. Friction is thus kept to a minimum even under adverse environmental conditions, with no threat of contamination of the optics by the lubricant.

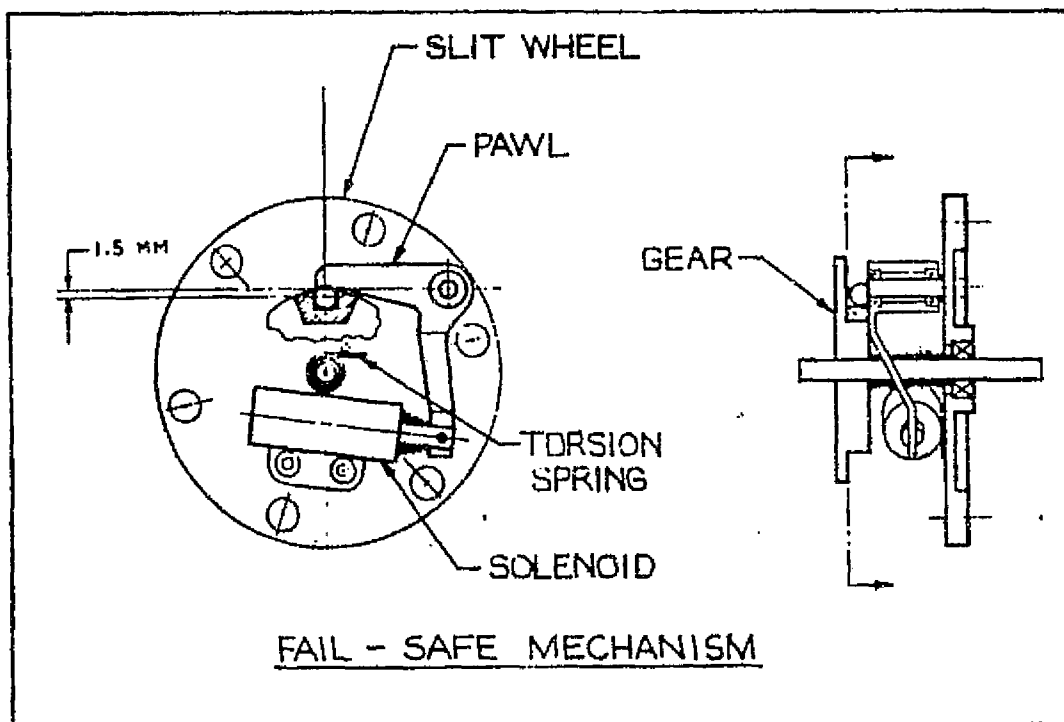


Figure 3-9 Fail Safe Mechanism (Typical)



3.4 ELECTRONICS AND DATA HANDLING

The High Speed Point/Area Photometer (HSP/AP) electronics subsystem will consist of the electronics associated with two point detectors, one area detector, mechanisms control electronics, command and housekeeping telemetry electronics, and memories. As shown in the functional block diagram (Figure 3-10), each detector has an individually variable power supply, processing electronics, and associated memory. In addition, the GFE supplied Intensified Charge Coupled Device (ICCD) area detector requires a scan and sync system for data readout, a detector cooler, and an analog or a photon mode of operation selector.

The mechanism drive electronics, low voltage power supplies (LVPS), housekeeping telemetry electronics, and instrument controlling logic is shared by all components of the instrument. The instrument electronics interfaces with a remote module of the SI C&DH system for all data multiplexing and command distribution.

3.4.1 DATA PROCESSING

Data processing is provided for the two point detectors (Image Dissector Sensors- IDS) and the ICCD area detector.

The signals from the point detectors are amplified and discriminated to obtain photon pulse rate data. Pulses are accumulated in a 16 bit counter which is re-set under program control. The counter words are transferred directly to the SI C & DH Remote Module for tape recorder storage during "integral mode" photometry. The counter words are stored in a 16K word memory for the synchronous mode photometry. In the synchronous mode the counts are time segregated and added for a programmable

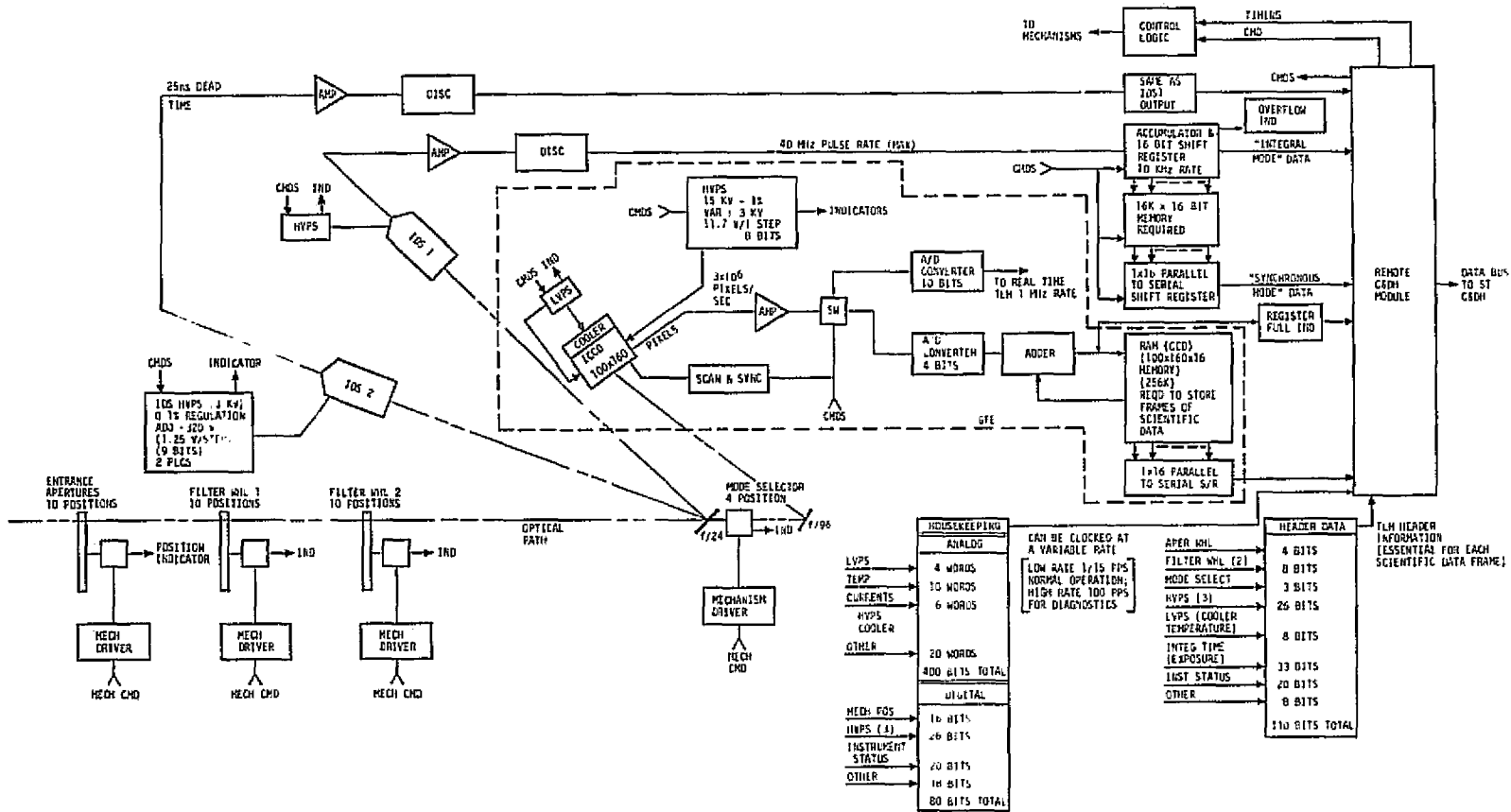


Figure 3-10 Functional Block Diagram



frame time, after which the memory contents are transferred to C & DH and cleared for a new frame. Data characteristics for the point detectors are summarized as follows:

IDS Dead time	25 nano sec
Max Pulse Rate	40 MHZ
Counter	16 bits
Line length	100 words
Line Sync	16 bit Barker code
Accumulation time	100 μ sec (Sync Mode) 1.625msec (Integ Mode)
Memory	16K words (Sync Mode)

The ICCD area detector is scanned with a 100x160 pixel format. The data is converted to 10 bit digital for transmission in the analog mode. A 4 bit conversion is used in the photon counting mode and pixels are added for a programmed time frame. A 100x160x16 bit CCD memory is used for frame storage. The memory data is transferred to the SI C&DH following each frame, and cleared for a new frame. Data characteristics for the ICCD area detector are summarized as follows:

Format	100 x 160 pixels
Pixel Rate	3×10^6 pixels/sec
Encoding	10 bits realtime 4 bits (count mode)
Counter	16 bits (count mode)
Line length	160 words
Line Sync	16 bit Barker Code
Memory	256K bits (count mode)
Minimum Integration Period	12.5m Sec (count mode)
Max. Integration time	300 sec (Analog mode)



In addition to the basic scientific information, certain header information is required for each frame of scientific data. This data will include mechanism positions, power supply voltages, integration or exposure time, etc., that is, all engineering information required for scientific data reduction. It is recommended that this information be inserted into the scientific data stream either immediately prior to or immediately following each frame of scientific data. Although much of the header information will be redundant with, and could be extracted from normal housekeeping data, insertion into the scientific data stream permits a clean separation between scientific and strictly engineering data, facilitating the data reduction later. Header information can be stored in a buffer memory, entered for each frame of scientific data and then inserted at the appropriate time into the scientific data stream. In addition to the instrument developed header data, the ST pointing, drift rate, etc. are required and should be included in the scientific data stream.

The HSP/AP will require approximately 40 analog measurements (temperatures, voltages, currents, etc.) and 80 digital bits (mechanism positions, on/off conditions, etc.) of housekeeping data. The analog housekeeping measurements will require an A/D converter of at least 10 bits resolution. This converter will be part of the C & DH Remote Module.



Two output rates for the housekeeping data are recommended. A slow rate of 10 to 60 seconds between measurements could be used for normal operation, and a much higher rate of 10 to 20 milliseconds between measurements could be commanded for diagnostic information when anomalies are suspected or for monitoring temporal conditions.

The SI C&DH should control the rate of the housekeeping data output upon ground command. Table III-4 is a summary of the data requirements of the HSP/AP for various operational modes. The operational characteristics are shown in Table III-5.

TABLE III-4
HSP/AP DATA REQUIREMENTS

Instrument Standby

40 Analog Measurements
21 Bits Digital Housekeeping

Instrument Preparation

40 Analog Measurements
50 Bits Digital Housekeeping

Acquisition (ICCD Analog Mode - Real Time)

40 Analog Measurements
80 Bits Digital Housekeeping
160 K Bits/Frame, From A/D Converter

Science Data (Or Calibration) Operations

40 Analog Measurements
80 Bits Digital Housekeeping

- Point Detector 1 or PD 2
160 Kbps from Accumulator in Integral Mode
10 Kbps from Memory in Synchronous Mode
- ICCD Photon Counting Mode
12 Kbps from Memory
- ICCD Analog Mode
Same as Acquisition Mode

TABLE III-5
HSP/AP OPERATIONAL CHARACTERISTICS

Detector	Format	Exposure Time	Data Output (Bits)	Memory Required (1)	Housekeeping Telemetry (2)	Command Requirements (3)
Point (IDS)	$\leq 1\text{mm}$	100 sec To Minutes	Max 1.6×10^4 /Sec	Yes	480 Bits	175 Bits
ICCD - Digital	100 x 160 Pixels	Seconds to Hours	2.56×10^5 Bits/Picture	Yes		
ICCD - Analog	100 x 160 Pixels	Seconds to Minutes	1.6×10^5 /Picture	No		

(1) Assumes no memory required for ICCD Analog Mode.

(2) Assumes all analog telemetry at 10 bits accuracy.

(3) Basic command requirements, these commands will require repeating during normal operation.





3.4.2 HSP/AP Memories

The point detectors will each require 16K by 16 bits of memory for storage of synchronous mode data counts, as shown in the functional block diagram Figure 3-10. The minimum access time is 100 μ sec (minimum accumulation time), which allows implementation with readily available MOS devices.

The ICCD also requires 16K by 16 bits of memory for storage of synchronous mode data counts, as shown in the functional block diagram Figure 3-10. The minimum access time is 12.5msec (minimum integration time) which allows again the use of MOS devices.

Table III-6 summarizes both memory and tape recorder storage requirements.

3.4.3 HSP/AP Command and Control Electronics

The command and control electronics will interface with the SI C&DH. Remote Module for control and timing functions and will:

- Receive and decode all instrument commands (mechanism positions, detector parameters, exposure time, telemetry dump, etc.).
- Control the instrument during all modes of operation.
- Provide memory and telemetry synchronization signals upon command.
- Respond to memory overflow or register full as required.

Exposure resolution to 1 ms \pm μ s is possible using a 1 MHz clock. Since timing control is required for all experiments, we recommend this clock be provided by the SSM.

TABLE III-6
HIGH SPEED POINT/AREA PHOTOMETER MEMORY REQUIREMENTS ⁽¹⁾

HSP/AP Control	Point Detectors		Area Detector Photon (Bits)	Header Data (Bits)	Housekeeping (2) Analog Digital (Bits/Min)	
	Number 1 (Bits)	Number 2 (Bits)				
CCD Memory			256K	1600		
MOS Memory	256K (Sync Mode)	256K		1600		
Mag Tape	256K/sec (Integral Mode)	256K/sec	9 x 10 ⁹ Bits (300 sec analog mode integration)		400	80

(1) Assumes a buffer memory for all detectors except the ICCD in the analog mode.

(2) Assumes the minimum recommended data readout of one measurement/minute.





Many operations of the instrument can be adequately controlled by programmed sequences stored in the SI C & DH. For example, a "Standby Mode" sequence could (1) turn on selected low voltage power supplies; (2) allow monitoring of instrument voltages and temperatures; (3) provide initial position commands to all mechanisms; (4) provide initial or reduced voltages to all detectors; and (5) control any other predefined or known condition or operation.

Table III-7 describes typical HSP/AP preparation modes. Tables III-8 through III-10 show typical operations for target acquisition, calibrate, and scientific data taking operations.

The complexity and memory requirements of the command and control logic will be minimized by the SI C & DH concept, with a Remote Module of the C & DH located within the HSP/AP. The instrument system can then consist of mechanism drivers and commands- in/responses-out and certain logic for the modes of operation.

The most difficult HSP/AP observing sequence from a timing and accuracy requirement is the synchronous photometry mode of operation. Exposure timing of 100 μ s must be implemented to ± 1 μ sec accuracy. This will require a small dedicated HSP/AP controller. The central SI C & DH controller will operate the instrument in all modes except the synchronous photometry mode. A simple HSP/AP processor could be dedicated to this mode of operation. This would provide the desired accuracy for this operation and maintain the SI C & DH concept. Operational sequences can be written days in advance, then entered into the SI C & DH memory just prior to execution.



TABLE III-7
TYPICAL HSP/AP PREPARATION MODES

STANDBY MODE

1. Turn on low voltage power supplies
2. Monitor instrument conditions
 - A. Temperature
 - B. Voltages
 - C. Position of mechanical devices
3. Command instrument to initial mechanical positions (i.e. mechanisms positions, etc., to standby)

INSTRUMENT PREPARATION

1. Select mechanical positions required for operation
2. Select detector
3. Power to cooler (if ICCP selected)
4. Select detector operational parameters
5. Power to memories as required
6. Select exposure time
7. Await command(s) for instrument mode of operation

TABLE III-8
HSP/AP TARGET ACQUISITION MODE

1. Select mechanism positions
2. Command ST to selected target
3. Power up detector, appropriate circuitry, and TLM
4. Perform acquisition verification
 - Real-time ground verification
 - Delayed transmission/verification
5. Maintain point detector centering

NOTE: Operations 1 and 3 may have been performed during instrument preparations



TABLE III-9

HSP/AP CALIBRATE MODE

1. Command instrument to source acquisition conditions
2. Acquire calibration source (point or area)
3. Select calibrate mechanism positions
4. Power up selected detector(s) and associated electronics
5. Select exposure time(s)
6. Initiate calibration
7. Repeat or select new calibrate conditions as required

TABLE III-10

HSP/AP OPERATE MODE-SCIENTIFIC DATA COLLECTION

1. Acquire and verify target acquisition
2. Select operate mechanism positions
3. Power up selected detector and associated electronics
4. Select exposure times
5. Perform exposures as required
6. Repeat 2,3,4 and 5 for next detector if required
7. Reverify target acquisition as desired between operations
8. Recalibrate as determined necessary by stabilities, change in operations, etc.

Section 4 .

INTERFACES WITH OTA AND SSM

4.1 OPTICAL INTERFACE WITH OTA

The optical interface between the OTA (Optical Telescope Assembly) and the SI's (Science Instrument) is considered in five parts:

- OTA/SI performance requirements
- OTA design
- Focal plane access
- OTA image quality/field correction
- Performance-influencing factors
 - Optical tolerances
 - Pointing jitter
 - Stray light

A summary of OTA minimum performance requirements is given in Figure 4-1. The difference between the design wavefront error of $\lambda/20$ rms OPD at 632.8 nm and the implied $\lambda/13.5$ error required to meet the 60 percent encircled energy requirement in a 0.075 arc-sec radius circle for the OTA provides for hardware contingency.

The portion of the ST performance budget allocated in the OTA is shown in Figure 4-2. The first major division of performance responsibility is between image motion and image quality. The first of these is attributed primarily to the telescope pointing system, while the second is attributed to the quality of the OTA optics.

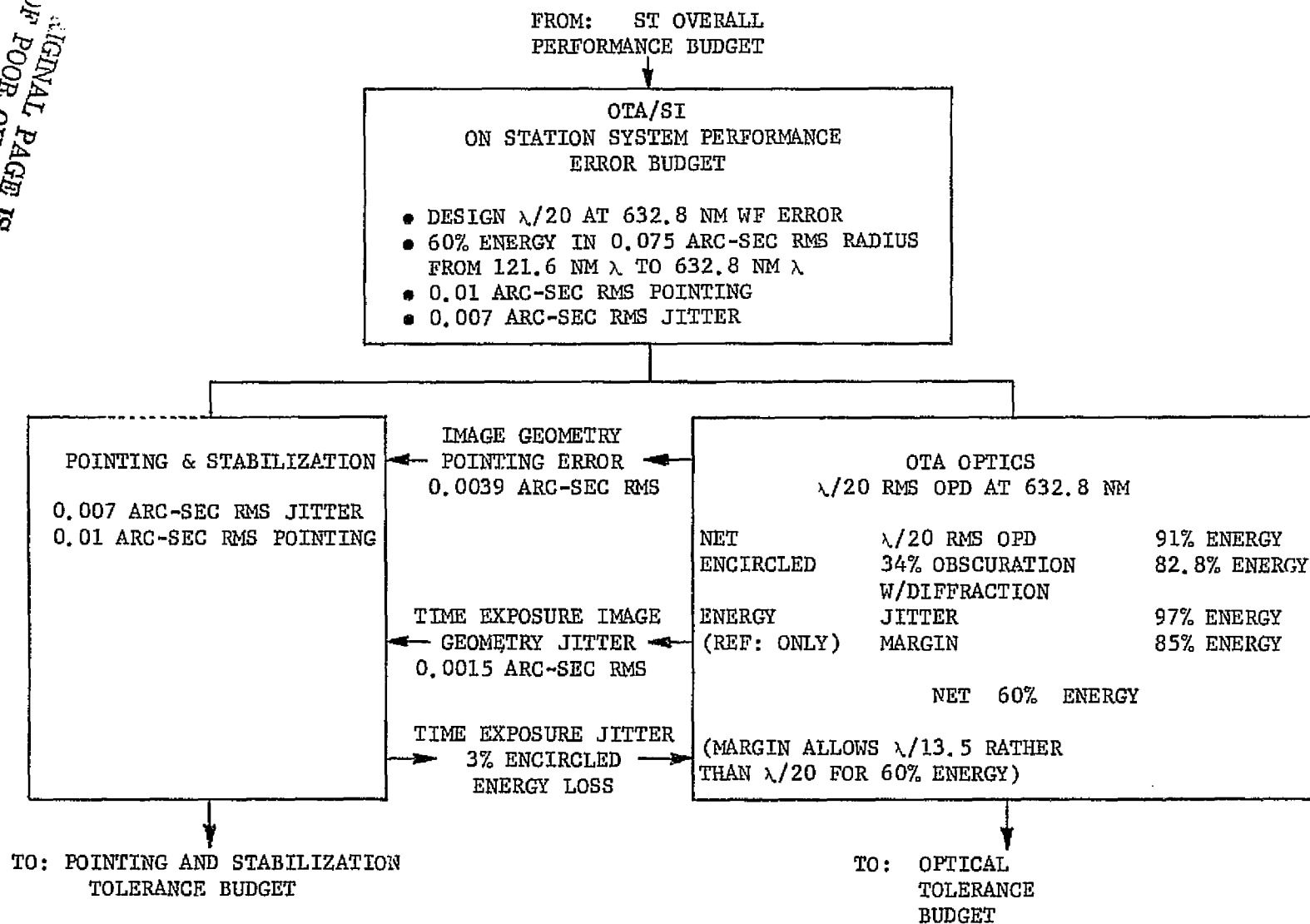
The optical design prescription for the OTA 2.4 meter Ritchey-Chretien and its first order parameters are summarized in Figure

CALCULATED PERFORMANCE (ON-AXIS)		
ENTRANCE PUPIL DIAMETER		2.4 M
SYSTEM FOCAL RATIO		f/24
DESIGN SYSTEM WAVEFRONT ERROR		.05 λ rms
DESIGN, TEST AND VERIFICATION WAVELENGTH		632.8 nm
CENTRAL OBSCURATION		34% (Maximum)
ENCIRCLED ENERGY		
0.075 ARC-SEC RADIUS ²		60%
WAVELENGTHS		121.6 nm to 632.8 nm
RESOLUTION		
RAYLEIGH CRITERION		0.1 ARC-SEC

Figure 4-1 Optical Performance Requirements

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Figure 4-2 OTA/SI Tolerance Budget

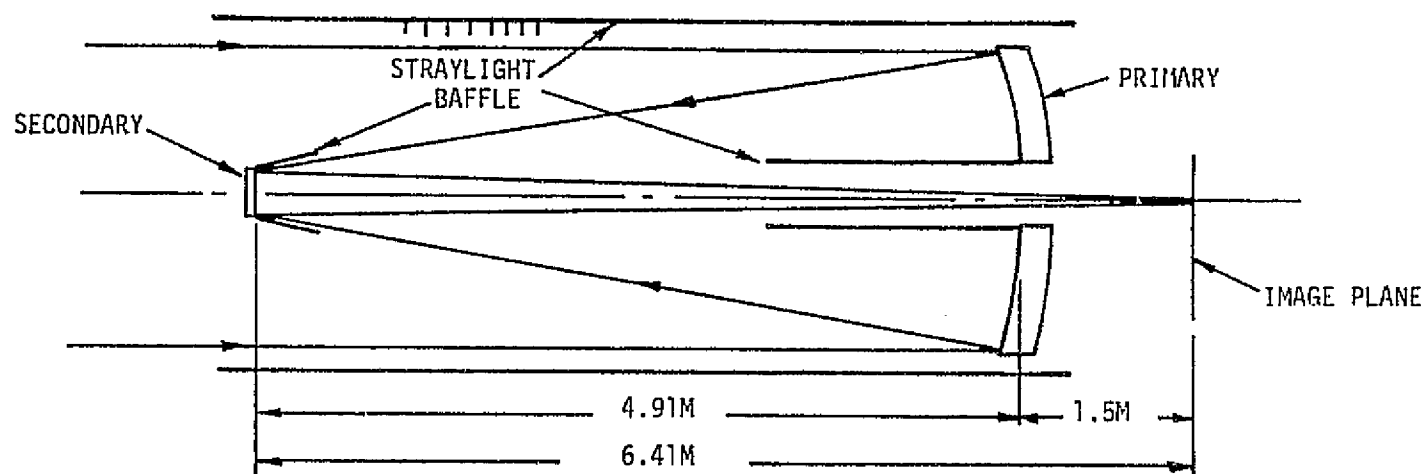
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4-3. The system is composed of two pure conic sections (hyperboloids) and nominally provides a geometrically perfect image on-axis. Off-axis, the system, as with all Ritchey-Chretien, is afflicted by field curvature and astigmatism. Details of system performance follow, but note that the actual design central obscuration is 31 percent. This is 3 percent less (72 mm of diameter) than the maximum 34 percent allowed. The implied design margin is available for further baffle design, and if not used provides additional performance margin.

The 28 arc-minute unvignetted field of view provided by the Ritchey-Chretien is allocated among the science instruments, pointing system and figure sensors as shown in Figure 4-4. Four 90° unvignetted segments of image are provided for the axial science instruments. Each extends a maximum of 9 arc-minutes (150 mm) from the OTA optical axis. The fifth science field, taken from the center of the OTA Field of View, is allocated to the f/24 Field Camera. The remainder of the field, from 9 to 14 arc-minutes, is reserved for the offset tracking sensor. The areas of the focal plane made inaccessible by the figure sensor pickoff mirrors and the structural components between modules are also shown.

Within the telescope field of view astigmatism and field curvature are the only significant aberrations present. These aberrations are detailed in Figure 4-5. The astigmatism, field curvature and small amount of distortion of the 2.4 meter ST Ritchey-Chretien are shown in the telescope's f/24 image plane map. Out to a radius of about $4\frac{1}{2}$ arc-minutes compromise foci are available where diffraction-limited image quality can be provided, at 632.8 nm wavelength, for small regions of the focal plane. Beyond this point optical correction must be provided to achieve diffraction limited quality.



Elements

- Primary - ULE Hyperbola, 11.04m Radius, 5.52m EFL, 2.4m Aperture, $f/2.3$
- Secondary - ULE Hyperbola, 1.358m Base Radius, 10.43 Magnification, 0.31m Aperture, $f/2.23$

System

- Aperture 2.4 m
- Focal Ratio $f/24$
- Linear Obscuration Ratio 0.31
- EFL 57.6 m
- Back Focal Length 1.5 m
- Plate Scale 57.6 mm/mrad (16.76 mm/arc-min)
- Field of View Diameter 467 mm ϕ , 8.1 mrad, 28 arc-min
- Data Field Diameter 300 mm ϕ , 5.2 mrad, 18 arc-min
- Tracking Field Size 1.5×10^{-5} sr (180 arc-min)²
- Coating 500Å to 800Å al w/250Å MgF
- Wavelength Range 100 nm to 1 mm
- Spatial Resolution (at 633 nm) 0.48μ rad (0.1 arc-sec) Rayleigh

Figure 4-3 OTA Optical Design

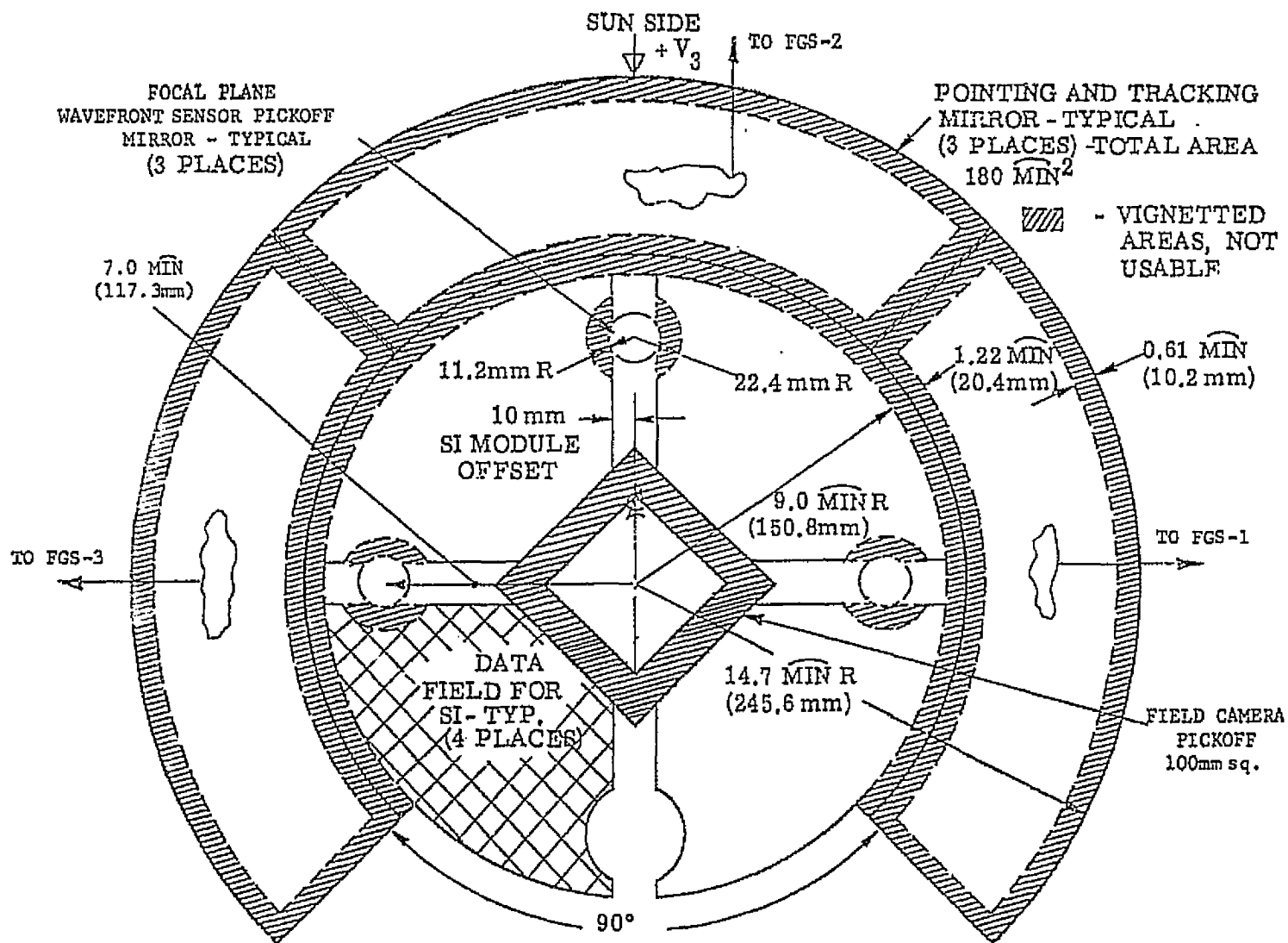


Figure 4-4 f/24 Focal Plane

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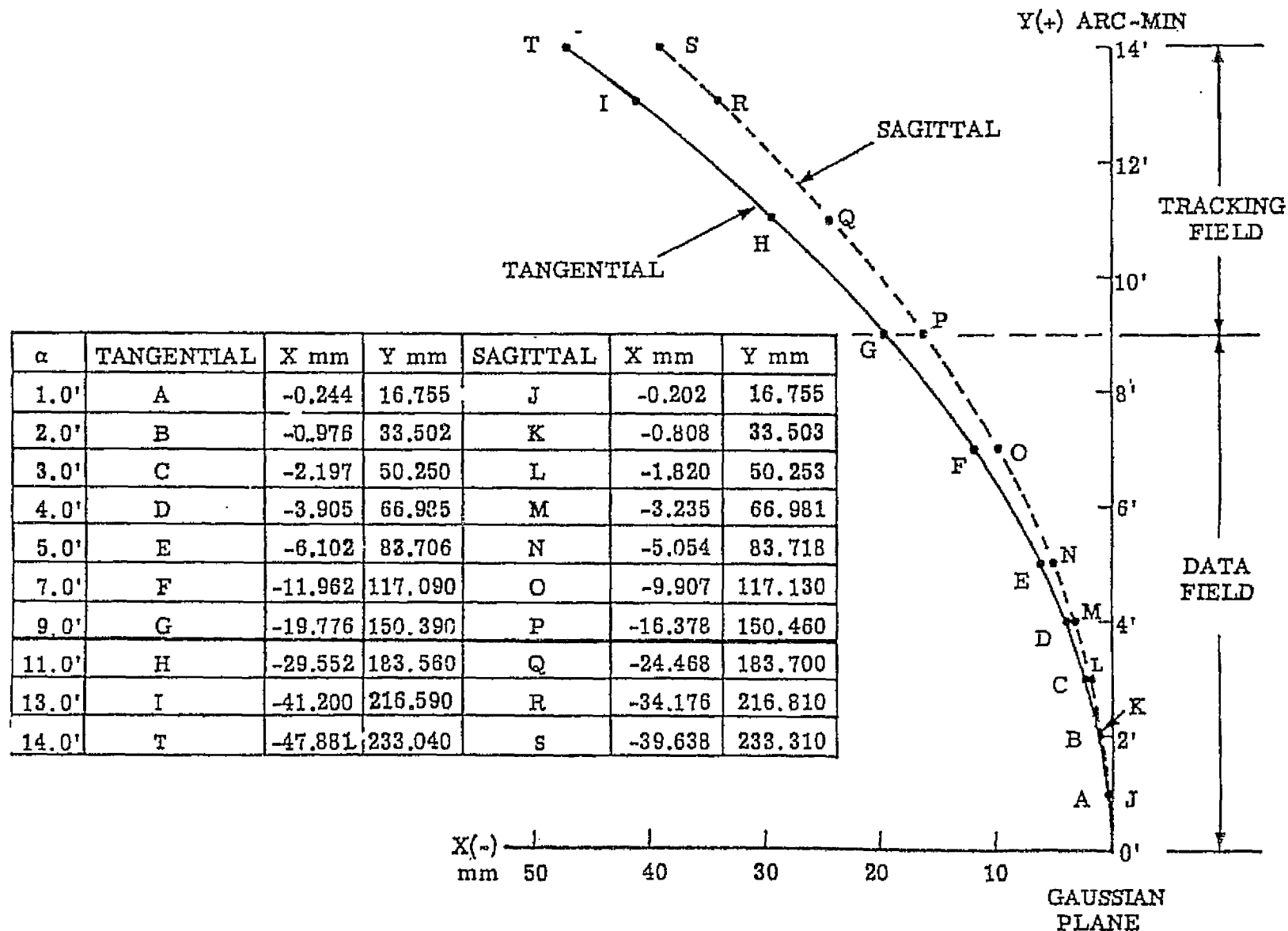


Figure 4-5. Focal Plane Topography

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In addition to the aberrations detailed in Figure 4-5, the diffraction effects inherent in the baseline OTA design modify nominal performance. Figure 4-6 summarizes these characteristics and shows their effects on performance. The vertical marks indicate the nominal design points of the parameters for the preliminary design OTA.

Beyond the nominal telescope design performance, the assigned optical tolerances determine the ultimate performance. The tolerance allocation is made so as to achieve $\lambda/20$ at 632.8 nm wavefront error on station. This near diffraction limited performance as provided by the OTA is not universally required by all instruments.

The instruments are designed and their tolerances are allocated to provide their required performance with the OTA budget taken into account.

The OTA to SI interface tolerances are absorbed into the OTA tolerance budget and do not burden the instrument designs.

The preliminary design optical tolerance budget, as it evolved from the Phase B study is shown in Figure 4-7. It provides for initial ground setup, residuals after orbital corrections and system drifts between calibration periods.

Figure 4-8 is the computed expected performance of the OTA determined by evaluation of the completed preliminary design and is now that system's tolerance budget. Note that the required design performance of $\lambda/20$ is slightly exceeded. This may be interpreted as additional design margin or as a relaxation of the baseline 15 to 30 days calibration cycle.

The final set of tolerances defining the OTA/SI interface are the instrument module mounting location accuracies and stabilities.

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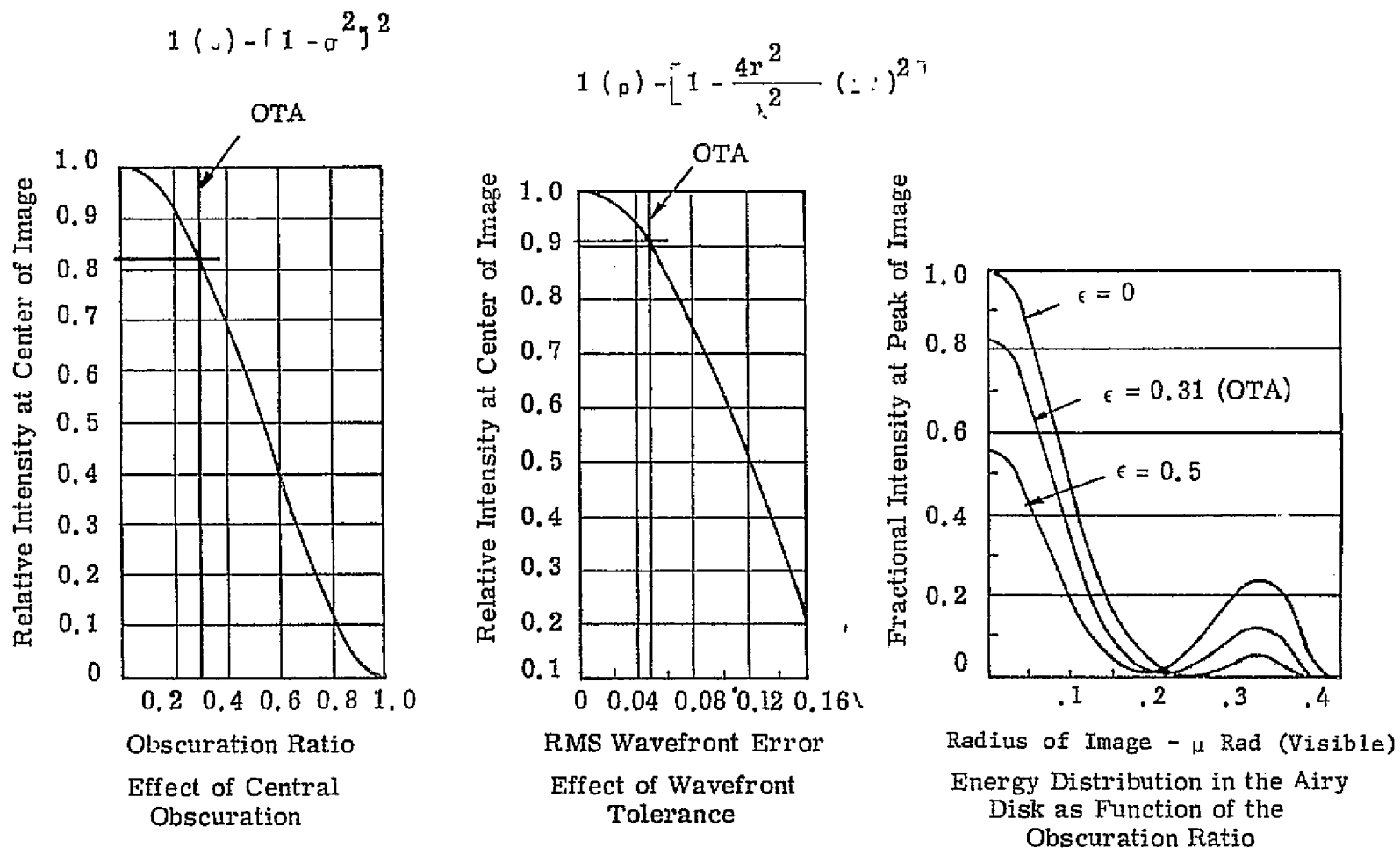


Figure 4-6 OTA Nominal Performance

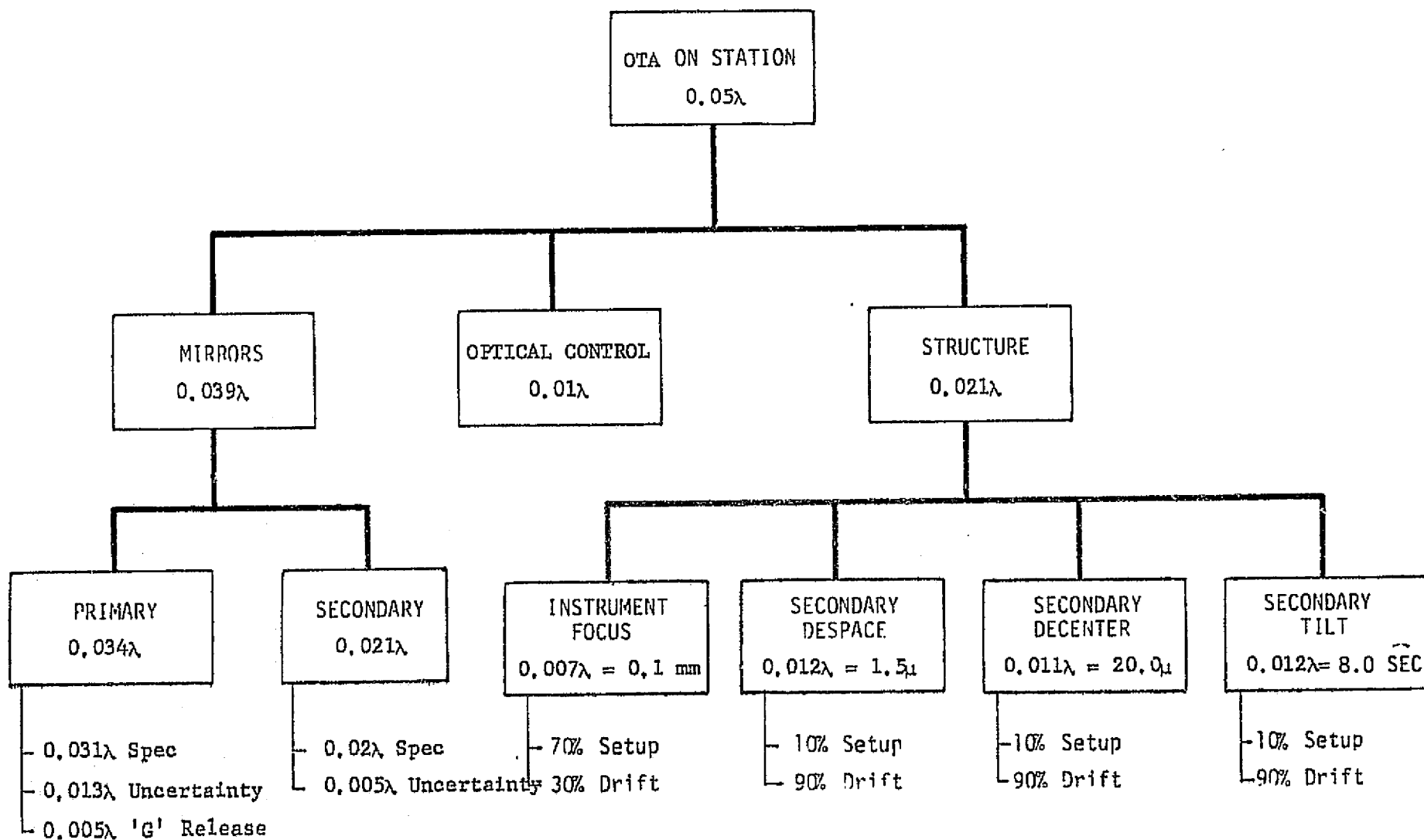


Figure 4-7 OTA Tolerance Budget Preliminary Design

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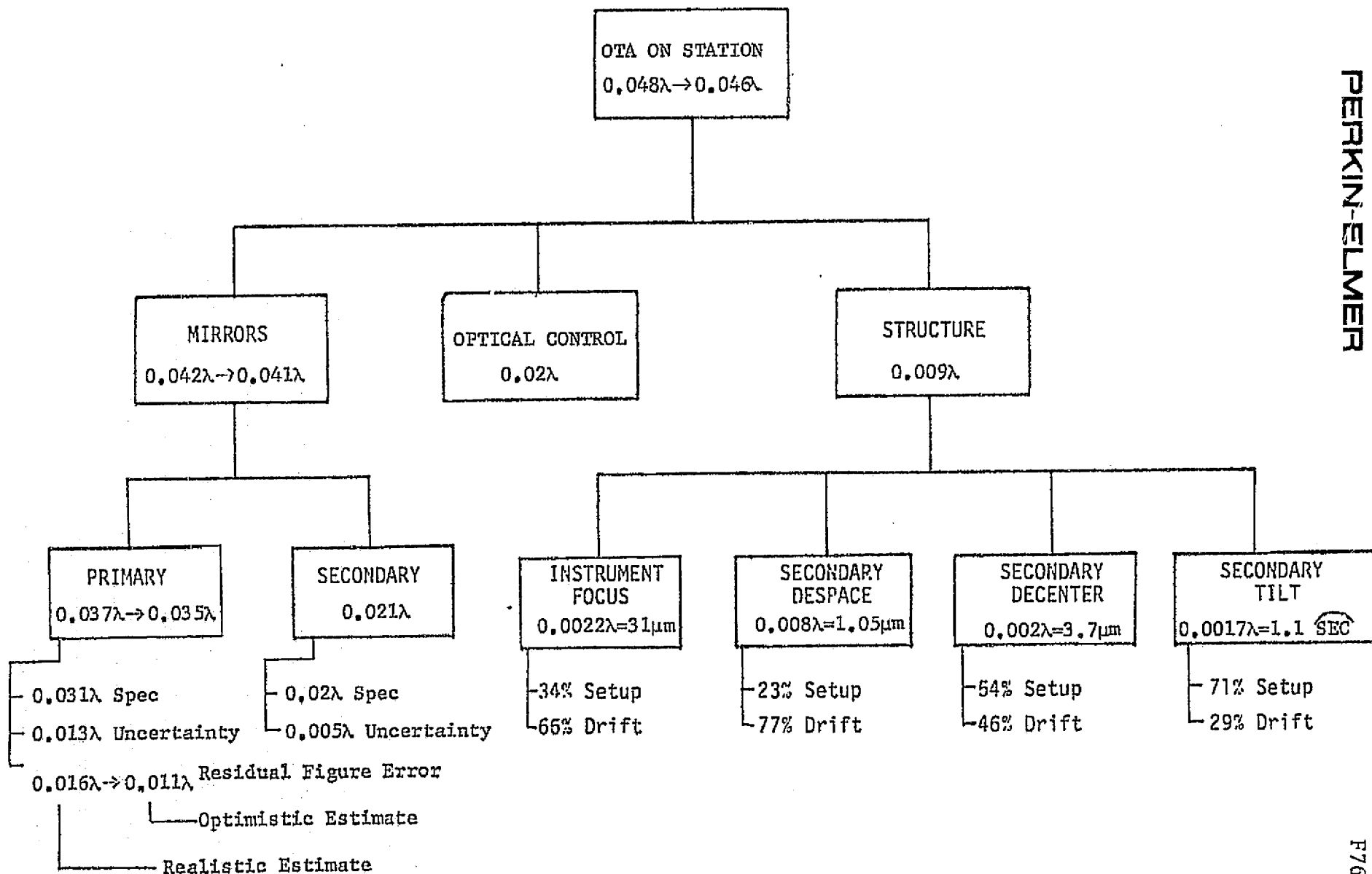


Figure 4-8 OTA Computer Performance Preliminary Design

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These tolerances are summarized for both the accuracies required for initial instrument placement and for drift over a calibration period in Figure 4-9. The optical RMS OPDs induced by these tolerances are absorbed into the OTA structures tolerance budget in the overall $\lambda/20$ RMS at 632.8 nm wavelength budget. The numbers represent the accuracy and stability to which the SI modules will be held by the OTA FPS with respect to the OTA. Tolerances within the instrument module, between instrument components and the module mounting points, are included within the instrument budgets.

4.2 ACQUISITION OF TARGET

The OTA Fine Guidance Sensor (FGS) incorporates a means for pre-setting the tracking point to an accuracy of 0.0022 arc second (1σ) after on-orbit calibration. This setting accuracy is accomplished by a set of 18-bit encoders calibrated to 0.001 arc second and a vernier interpolating servo with similar precision.

Since the rms jitter of the data star is 0.007 arc second (1σ) and the incremental setting accuracy is 0.0022 arc second (1σ for all axes), it will be possible to control via the ST command system the data star to less than 0.01 arc second. However, the precision of knowledge of the relative positions of the data star and the guide star will probably be more like ± 0.1 arc second. Therefore, it is planned that the ICCD Camera in an imaging mode will observe the telescope field defined by the field stops. If the object of interest is the brightest object in the vicinity of the stop, then the ST computer can be programmed to peak detect the most intense centroid in the camera memory, subtract the coordinates of this centroid from the coordinates of the center of the stop (at the camera) and convert this algebraic difference into an FGS command. The FGS would then reduce the difference to zero. If the data star is such that a simple peak detection scheme is

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• SI TO OTA TOLERANCES FOR ON-ORBIT INSTRUMENT REPLACEMENT

$$X = \pm 0.1 \text{ mm}$$

$$\alpha = \pm 0.5 \text{ mrad}$$

$$Y = \pm 0.1 \text{ mm}$$

$$\beta = \pm 0.5 \text{ mrad}$$

$$Z = \pm 0.026 \text{ mm}$$

$$\gamma = \pm 0.5 \text{ mrad}$$

• LONG TERM INSTRUMENT STABILITIES (BETWEEN OTA/SI CALIBRATIONS AND DURING EXPOSURES)

$$X = \pm 0.005 \text{ mm}$$

$$\alpha = \pm 0.5 \text{ mrad}$$

$$Y = \pm 0.005 \text{ mm}$$

$$\beta = \pm 0.5 \text{ mrad}$$

$$Z = \pm 0.051 \text{ mm}$$

$$\gamma = \pm 200 \text{ } \mu\text{rad}$$

• THE INDICATED TOLERANCES PERMIT UTILIZING FULL OTA CAPABILITY

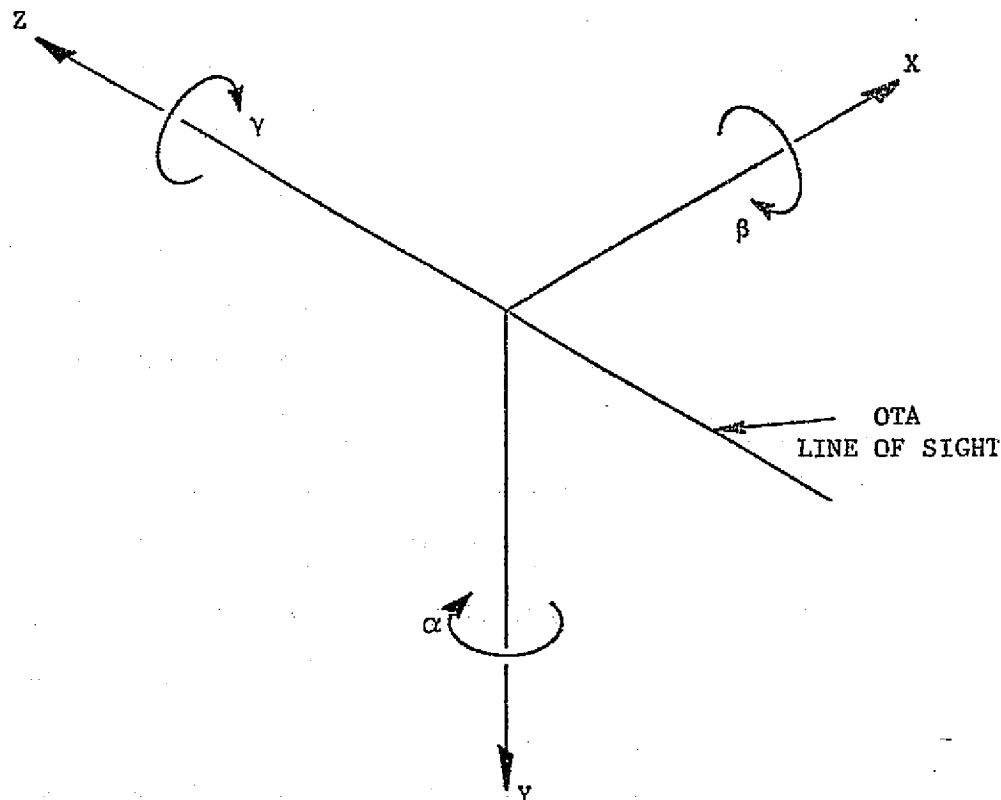


Figure 4-9 SI/OTA Interface Tolerances Allocation

not feasible, an option is to transmit the camera image to the ground for observer analysis and FGS command generation.

The FGS incorporates means for compensating the differential velocity aberration. This assures that reacquisition will occur with accurate pixel-by-pixel reregistration. Furthermore, the 5 arc minute diameter acquisition field of the FGS affords a secure reacquisition regardless of accumulated pointing errors during earth occultation. Reacquisition requires less than 30 seconds of time for a ± 30 arc second pointing error. The search time increases as the square of the pointing error.

4.3 STRUCTURAL AND THERMAL INTERFACE

4.3.1 Structural Requirements/Interface with OTA

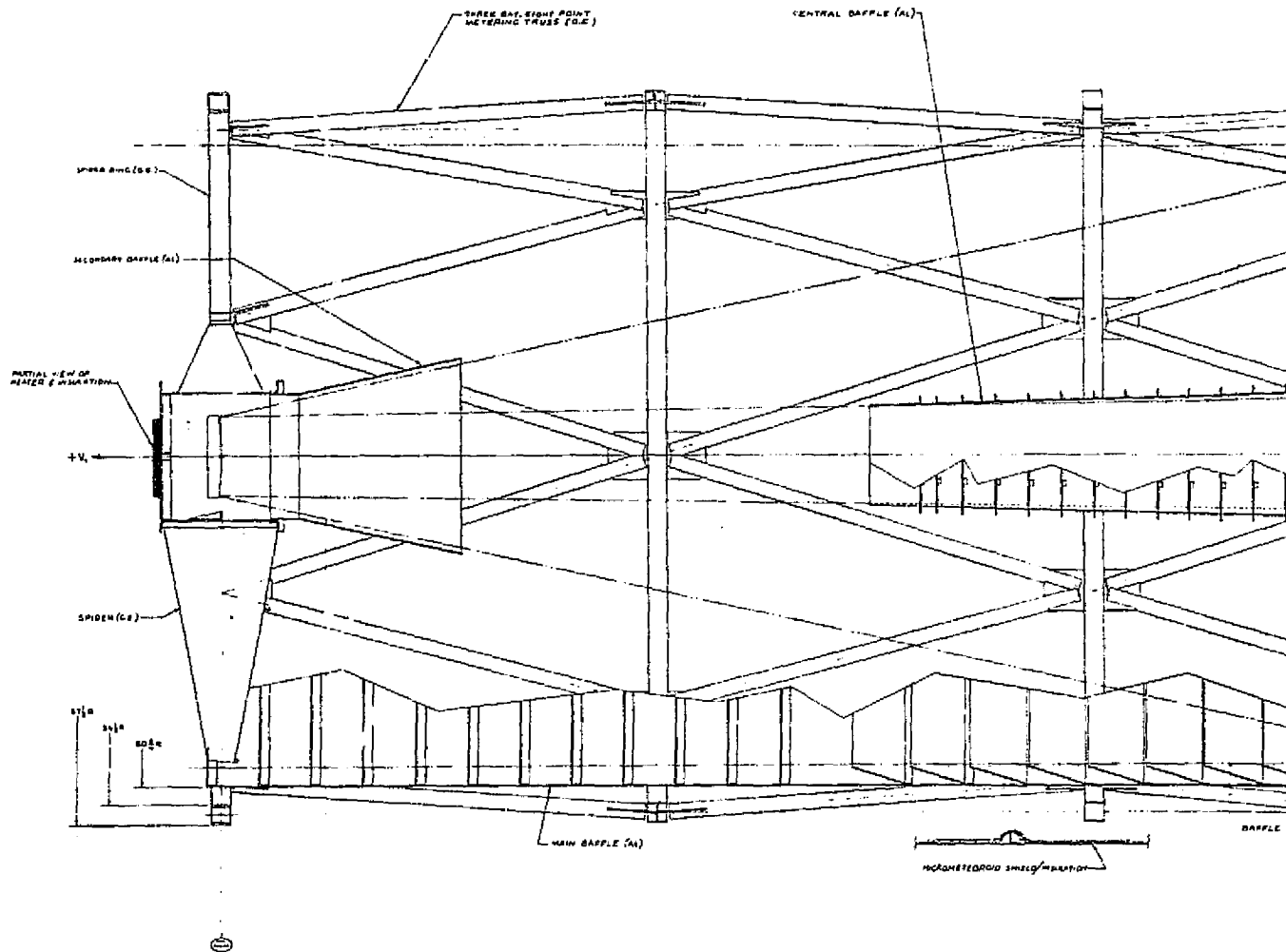
The HSP/AP will be mounted into one of the four axial modules of the OTA. Figure 4-10 illustrates the general configuration of the OTA and shows the location of the radial bay section, focal plane structure and axial science instrument complement. Figure 4-11 shows the relationship of the axial science instrument modules to the OTA optical axes and solar input to the telescope.

Focal Plane Structure

The prime requirements for the FPS are as follows:

- Maintain its locating surface (to which all instrumentation is attached) with respect to the optical axis to within a tolerance of 0.1 mm and with respect to the curved focal plane with a tolerance of 0.07 mm.
- Provide a means for registering all focal plane instrumentation to this mounting surface. In the case of the science instruments, the registration design

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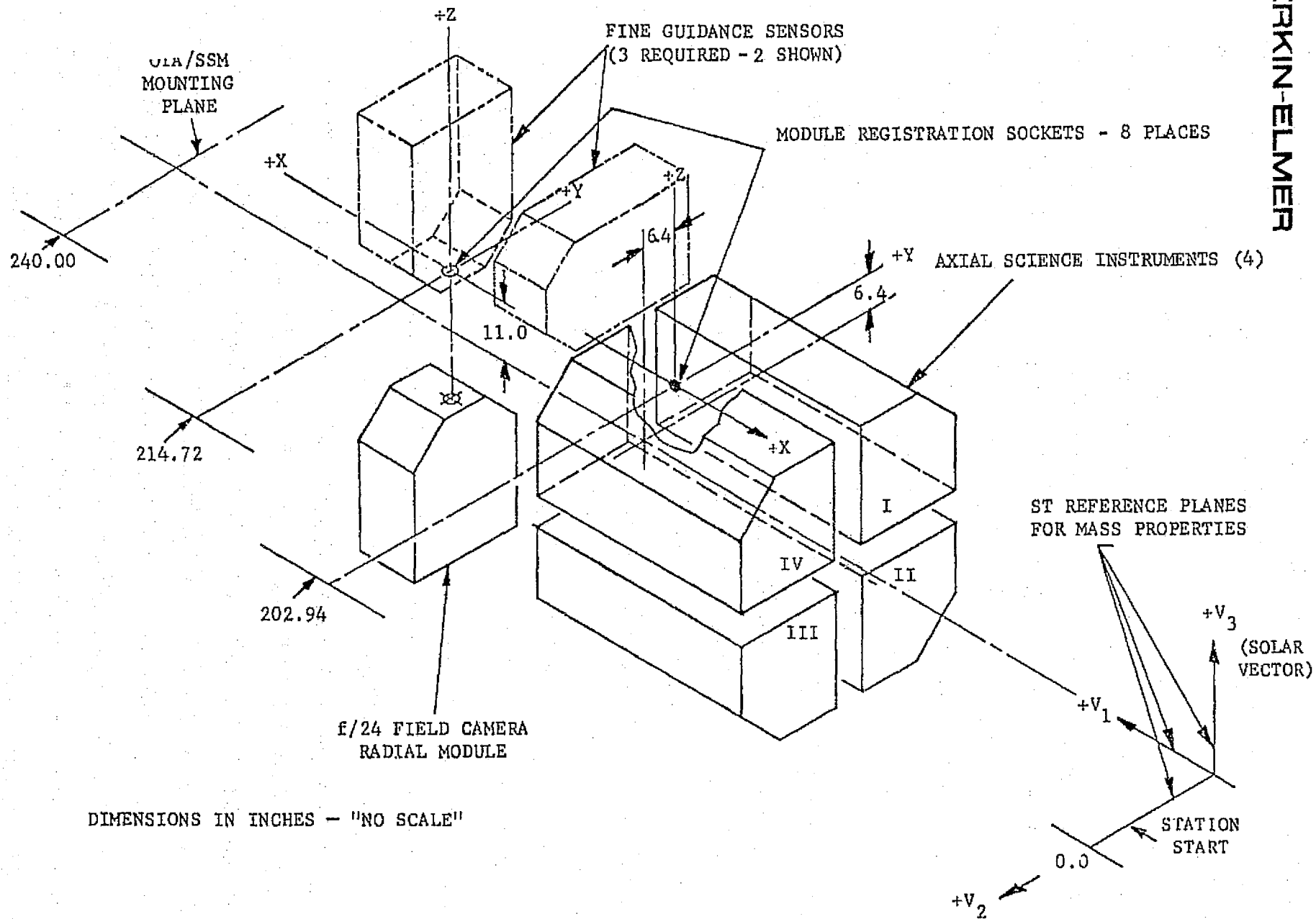


Figure 4-11 SI Radial and Axial Module Orientation

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must allow for repeatability of registration after orbital removal and replacement.

- Provide a stable surface, i.e., prevent relative motion between the science instruments and the Fine Guidance Sensors.

The design of the focal plane structure was driven by configuration requirements. Structural performance was achieved by material selection and member sizing, having first defined the mechanical or configuration constraints. The structure is designed to accommodate the four large axial science instrument modules and four radial bay modules. Three of the radial bay modules are for fine guidance sensor instrumentation, and the fourth contains the f/24 Field Camera. All of the science instrument modules (both axial and radial) are replaceable on orbit by a suited astronaut.

The principal design requirements for the focal plane structure are derived from the OTA system focus budgets and fine pointing accuracies. Focus shift allowed during an observation is 30μ total for this structure. This is achieved by using titanium and stabilizing the temperature of the structure to $\pm 2^{\circ}\text{F}$. Half of fine pointing error (0.005 arc-second) is budgetted for thermal effects during an observation. At the f/24 focus, 0.005 arc-second is equivalent to 1.4μ which then becomes the limit for any lateral change between a science instrument and its controlling star tracker (fine guidance sensor). This requirement is satisfied with a low expansion (Invar) mounting plate on the focal plane structure which is the mechanical reference for both the FGS and the SI modules.

The deflection of the center of the focal plane structure, relative to the primary mirror vertex, is 0.002 inch with the system

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vertical and with four 500 pound SI's installed. If this were permitted to exist as a gravity-release error, only $1/2\mu$ of secondary mirror motion would be required to correct it on-orbit. The 0.01 inch axial position tolerance is correctable with a 2μ secondary shift.

Because of the nature of ST, as a long-lived National Observatory facility, and the varying requirements of the present, and as yet undefined future, science instruments, the tolerances established for the FPS are driven by essentially the requirements of the most sensitive anticipated SI.

The structural design of each science instrument must therefore be developed from a review and consideration of the performance of the OTA and the tolerances associated with the reference ball detent, to provide a science instrument mounting surface which will support and stabilize the instrument optical system to the extent required to achieve the performance specification.

The general OTA configuration is directed toward an instrument module which will achieve the following:

- Provide a mounting reference to the ball detent - and flexible connection to two other points on the OTA structure.
- Enclose and protect the science instrument.
- Provide a thermal environment both to stabilize the instrument and provide a means of dissipating heat to the SSM.

Within each module an optical bench is provided onto which the key elements of the instrument are mounted and aligned. Mounting forces and deflections from the module mounting must not be transmitted into the optical bench.

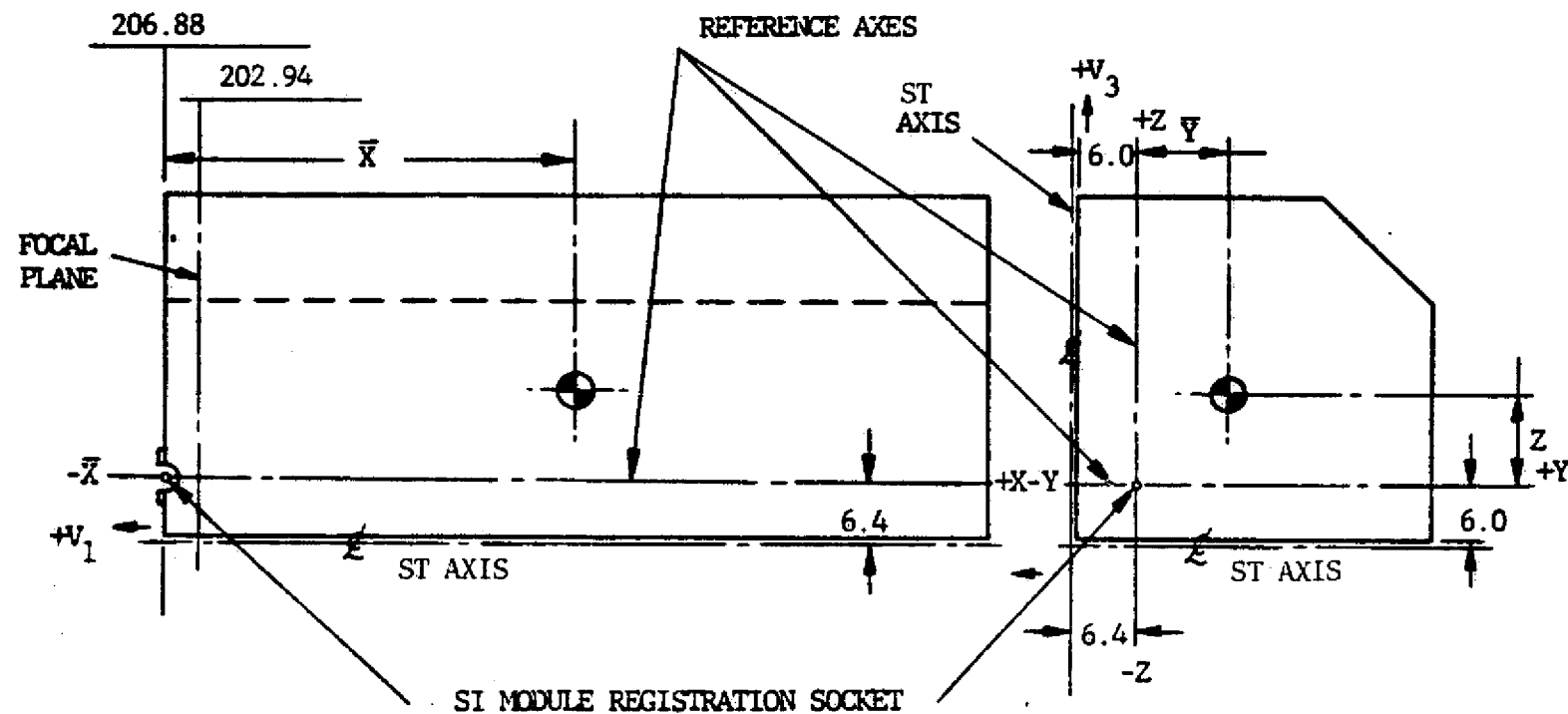
Axial Module/Alignment with FPS

The OTA axial bay science instrument module is illustrated in Figures 4-12 and 4-13. Interior space available to the SI designer, including his optical bench, is approximately 0.85 x 0.85 meter by 2.1 meters in length. As shown in Figure 4-13, the module structure avoids a tapered plane starting 0.25 meter from the corner nearest the OTA optical axis down to near the bottom corner of the module. This provides a significant optical entry area and avoids structure behind this entry; it is anticipated that most instruments will need this space for placement of SI optics and/or the detector. The SI designer will add a light metal cover in this area consistent with his entry requirements/SI design. The axial module will be constructed of aluminum and is estimated to weigh ~ 140 pounds.

A spherical ball socket mounted in the top surface of the module will interface with the locating ball detent on the FPS. Precise alignment/location of the detent/socket will assure that the module is located properly with respect to the OTA optical axis and will allow orbital maintenance, i.e., removal and reinstallation, by a suited astronaut.

A second socket on the base of the axial module, directly opposite the locating detent on the top surface, will accept the output of a restraining drum mechanism, this force securely restraining the module to all motions except rotation about the line between the two detents. A pin-slot on the module top surface (not shown) will prevent this rotation. As discussed later, these module loading forces will not introduce loads/deflections into the SI optical bench. Access to the instrument, after its installation into the module, will be via large access panels, on the outside surfaces of the module.

POSITIVE SIGN CONVENTION



TYPICAL FOR AXIAL INSTRUMENTS

Figure 4-12. Orientation Diagram and Reference Axes

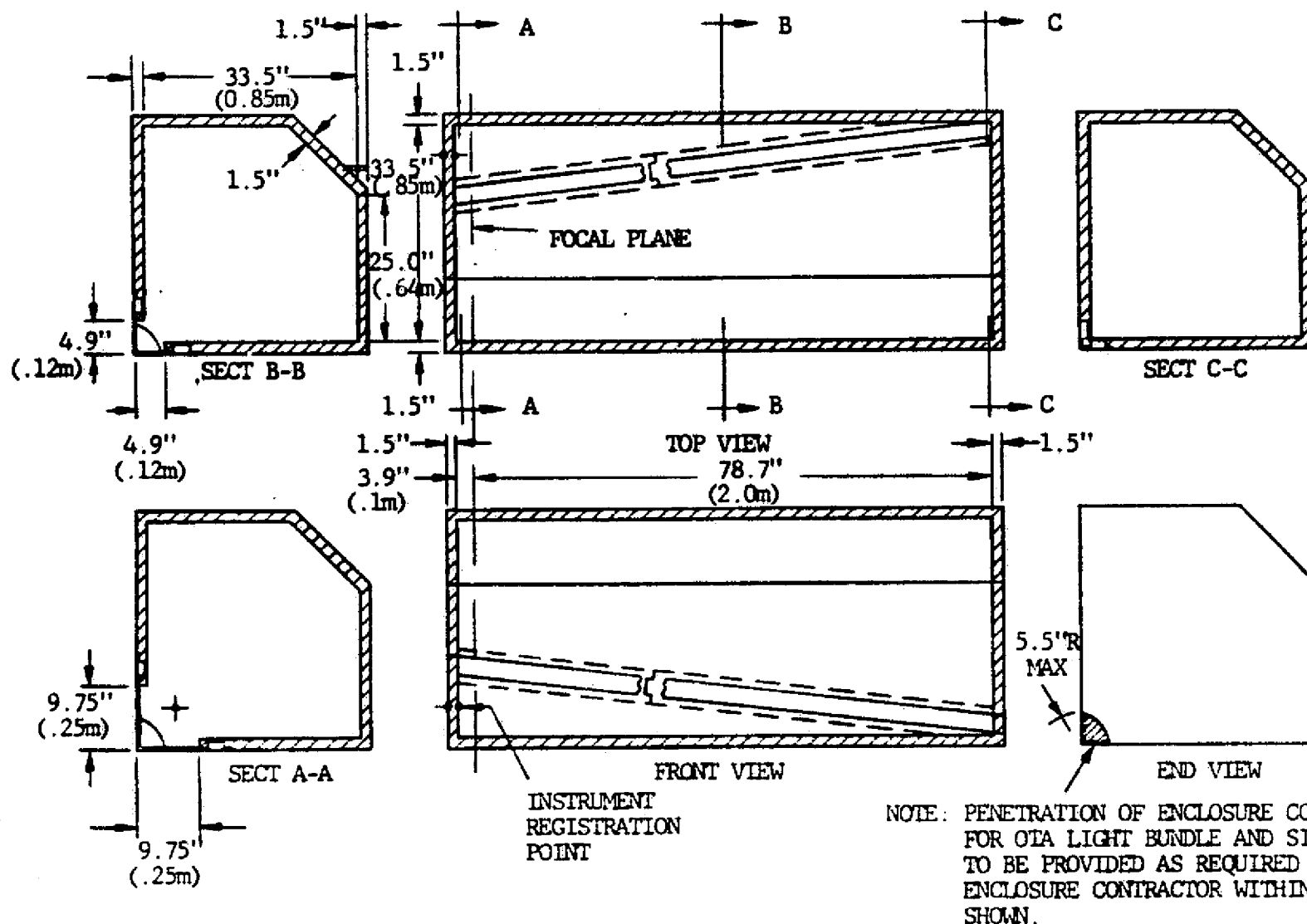


Figure 4-13. Axial SI Enclosure Interior Envelope

Optical Bench

The optical bench for the HSP/AP provides a rigid base integral with the instrument elements and permits easy access/installation of the instrument into the axial bay module. This optical bench will be kinematically mounted to the module base in order to prevent external moments from being introduced to the instrument.

Three tie down points will be provided to the module: A fixed mounting (constrained in all directions) at the front end adjacent to the module ball detent and two axially compliant flexure mounts at two points lower on the module wall. As noted in Section 3.3 and shown in Figure 3-7, structural plates bridge between the two "V" elements of the bevel, providing surfaces on which to mount the optics, mechanisms and detector. These also provide structural rigidity to the bench. Bench weight is estimated to be 63.5 kg (50 pounds).

4.3.2 Thermal Design

Due to funding limitation, thermal analysis was not conducted on the HSP/AP instrument, however indepth analysis was conducted on the Faint Object Spectrograph (FOS) instrument for the ST and is considered representative of the thermal constraints and thermal design concepts for the HSP/AP.

A discussion of the FOS thermal analysis may be found in the BBRC/Perkin-Elmer Final Report F75-24 entitled Phase B Definition Study of the Space Telescope Faint Object Spectrograph. A brief summary of that analysis is presented here in support of the HSP/AP instrument concepts.

It has been confirmed by analysis that it is feasible to maintain adequate temperature control of the proposed FOS instrument package. The design has been configured to be symmetrical so that heat may be rejected from the outer surfaces of the SI container. The instrument is thus truly modular and can be located in any one of the four available axial positions on the OTA. Both the structural and thermal integrity of the sensitive optical bench are enhanced by mounting the accessory electronic packages off of the optical bench so that both mechanical and thermal loads are transmitted directly to the SI enclosure walls.

The analysis has been based generally on the use of a thermally black enclosure and equipment surfaces with multilayer insulation so applied to the principal heat sources to minimize the heat transmission to the sensitive optical components. Utilizing black surfaces has the desirable additional effect of minimizing stray light reflections within the optical enclosure. Limited use of nonblack surfaces will be evaluated as part of a final design optimization effort when the precise thermal loading and coupling characteristics of the various equipment items has been more firmly established.



Although not specifically treated in this analysis, thermal control refinements such as heat pipes might well have some advantages in "local" heat flow management of the dimensionally sensitive detector units. Such considerations should also be evaluated at the appropriate stages of the instrument design process.

The general location of the heat generating, electronic packages was selected for this analysis to minimize the thermal coupling between them and the detectors. However, this relative juxtaposition is not considered critical and may be altered for other design objectives as they may develop.

An 89 node thermal coupling (135 radiation surfaces), model of the FOS assembly was completed. The design configuration used in this model was provided at an early phase of the redesign of the FOS. Subsequent changes of design, such as the locations of the electronics should not significantly alter the basic results of the FOS analyses which are: (1) that the full operating power of the instrument can be dissipated from the walls of the module to the SSM aft shroud even under the warmest conditions anticipated for the shroud and (2) temperature of the optical bench will always require the addition of heat to maintain a uniform gradient within the bench. Internal heat transfer involves both radiation and conduction but is dominated by radiation.

The specific criterion selected for cooling is that the system shall, on a steady state basis, be capable of limiting the temperature of the optical bench to 70°F at the highest environmental temperature. Analysis indicated that the temperature of the optical bench would vary along its length between 45 and 60°F. for the operating thermal loads. This provides a very conservative appraisal of the temperature maintenance capacity of the basic system design since the analysis includes both detectors



when in fact only one of the detectors would normally operate at any given time. In operation, the temperature of the optical bench is maintained at $+70^{\circ}\text{F}$ by thermostatically-controlled area heaters.

The design approach and conceptual configuration of the HSP/AP is similar to the FOS. It is by this similarity that we are confident that the approach to the design of the HSP/AP is within the capability of good thermal design practice. Although the HSP/AP instrument is considerably smaller in size than the FOS, the same techniques of modulating heat flow by means of active heaters if necessary to eliminate thermal gradients in critical elements and passive insulation can be employed to achieve the required system performance requirements. Thermal modeling and analysis will be conducted during the detail design phase for the HSP/AP.

Any cooling required by the ICCD detector is assumed integral with the ICCD assembly and therefore designed and included as part of that system.

4.4 WEIGHT

Table IV-1 is a listing of estimated weights for the HSP/AP.

The Image Dissector Sensor assembly weight was derived from previous builds of flight packages.

The area detector weights are as defined by GSFC plus 4 pounds for mounting, and radiation and scattered light shielding. The memory weight was provided by GSFC.

The instrument optical structure also includes the structure necessary to properly reference the instrument bench to the hard mount points of the SI standard container.



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Table IV-1
HSP/AP ESTIMATED WEIGHTS

Field Stop Assembly	2.3 kg	5 lb
Filter Wheel Assembly (2)	4.5	10
Relay Mirror Mounts (2)	0.9	2
Point Detector Assembly, 1 (IDS)	3.6	8
Point Detector Assembly, 2 (IDS)	3.6	8
Power Supplies IDS (2)	0.9	2
Preprocessing Elect. (2)	0.9	2
Area Detector Assembly (ICCD)	4.5	10
Area Detector Elect.	6.8	15
Memory	2.3	5
Detector Shielding	1.8	4
Control and Logic Elec.	2.3	5
Power Supplies	2.7	6
Drive Circuits	1.8	4
Monitor Circuits	0.9	2
Cables & Connectors	8.2	18
Instrument Optical Structure	22.7	50
Subtotal	70.7 kg	156 lb
Outer Box	63.5	140
Estimated Weight	134.2 kg	296 lb



4.5 POWER

4.5.1 HSP/AP Power Requirements

The HSP/AP power requirements have been investigated and an estimate made regarding power needed for each major function has been made. Table IV-2 is a tabulation of the estimated power required by the HSP/AP by function. The range shown is the uncertainty in the power estimate.

4.5.2 Power Profile

The power profile, Figure 4-14, shows the average of the high and low estimates indicated on the previous table.

Calibration is performed using external point or extended source. For the power values shown, the ICCD detector cooling is assumed ON at all times after instrument preparations. Instrument thermal control power is included. Some small wattage heaters may be necessary to eliminate temperature gradients across critical optical structures.

4.6 COMMAND AND DATA INTERFACES

The projected requirements for both command and data functions and their associated bit requirements are listed in Table IV-3. The table assumes a real time sampling rate of one sample per second or faster. However, it is possible to reduce the overall data handling requirements by either mode switching or sub-multiplexing in the telemetry system. The table classifies the data by type (engineering data, header data, etc.) and further consideration should be given to reducing sample rates thereby reducing the total data handling requirements.

Table IV-4 indicated the conceptual command sequence and gives a brief description of the command function.

Table IV-2
HSP/AP POWER REQUIREMENTS (WATTS)

Function	Standby	Instrument Preparation	Target Verification	Calibrate		Operate			
				IDS	ICCD	IDS	ICCD (Photon)	ICCD (Analog)	ICCD 2 IDS
Housekeeping, Digital	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4
Housekeeping, Analog	2-5	2-5	2-5	2-5	2-5	2-5	2-5	2-5	2-5
Low Voltage Power Supply	5-7	5-7	5-7	5-7	5-7	5-7	5-7	5-7	5-7
Image Dissector 1 ⁽¹⁾		2-3		2-3		2-3			2-3
Image Dissector 2 ⁽²⁾		2-3		2-3		2-3			2-3
IDS 1 Mem and Readout				4-7		4-7			4-7
IDS 2 Mem and Readout				4-7		4-7			4-7
ICCD Camera Head		10	10		10		10	10	10
ICCD Electronics		15	15		15		15	15	15
ICCD Memory			10		10		10	10	10
ICCD Cooling	10	10	10	10	10	10	10	10	10
Mechanisms and Drive		1-2 (Plus approximately 28W for 30 seconds during actuations)							
Control Electronics ⁽²⁾		1-10	1-10	1-10	1-10	1-10	1-10	1-10	1-10
TOTAL (Watts)	20-26	51-69	56-71	33-56	56-71	33-56	56-71	56-71	68-91

⁽¹⁾ Includes HVPS

⁽²⁾ Includes 1 to 4 watts for possible thermal controls.



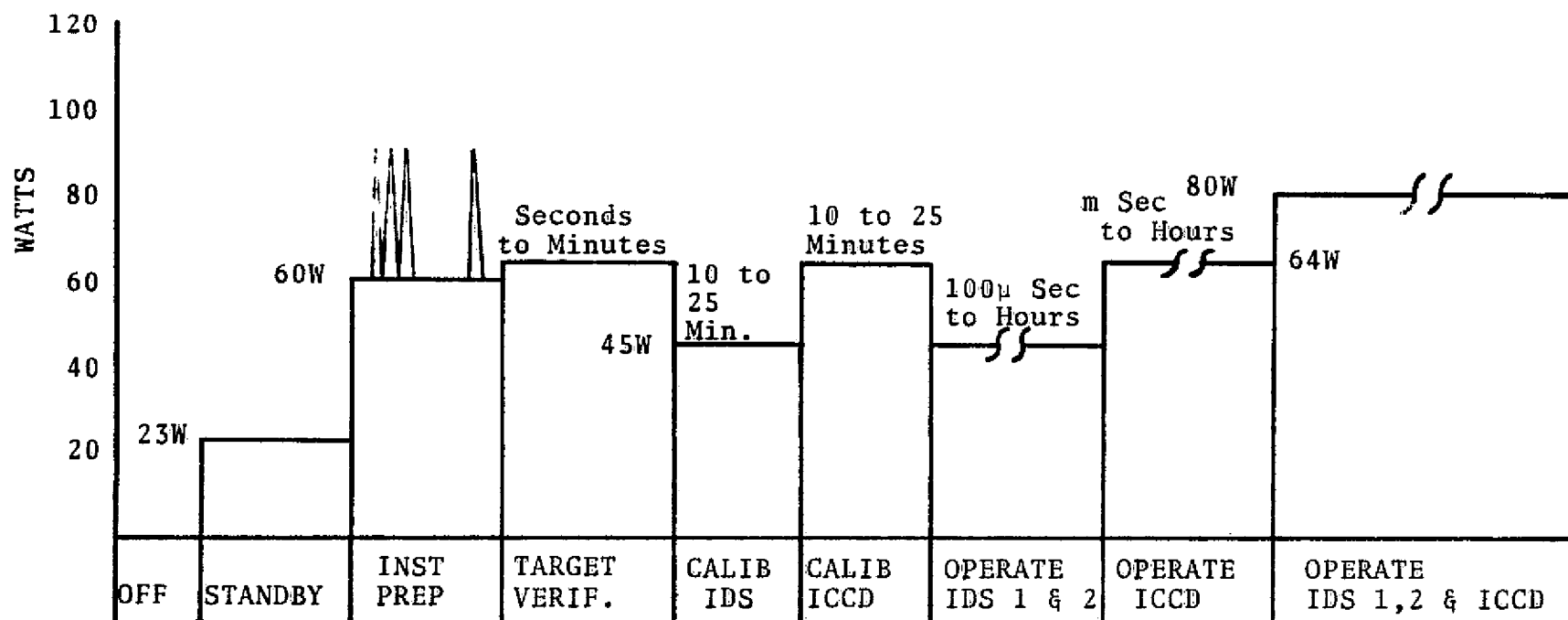


Figure 4-14 ST High Speed Point/Area Photometer Power Profile

Table IV-3
INSTRUMENTATION LIST - HSP/AP

Signal	Description	Signal Type	Range	Analog Accuracy	Number Of Bits	*Data Type
Main power monitor		D	On/Off		1	
Main power voltage		A	TBD	1%		3
Main power current		A	TBD	1%	8	3
Thermal mode		D	On/Off	-	1	1
Standby mode		D	On/Off		1	1
Acquisition Mode		D	On/Off		1	1,2
Calibrate Mode		D	On/Off		1	1,2
Operate Mode		D	On/Off		1	1,2
Aperture wheel		D	10 discrete positions		10	2
Filter wheel 1		D	10 discrete positions		10	2
Filter wheel 2		D	10 discrete positions		10	2
Area detector HVPS setting		D	As commanded		9	2
Area detector HVPS reading		A	TBD	1%	8	3
Area detector		D	On/Off		1	3

*1 - Operational Data

2 - Header Data

3 - Engineering Data



Table IV-3 (Continued)
INSTRUMENTATION LIST - HSP/AP

Signal	Description	Signal Type	Range	Analog Accuracy	Number Of Bits	*Data Type
Read		D	On/Off		1	3
Point detector HVPS #1 setting		D	As commanded		9	2
Point detector HVPS #1 reading		A	TBD	1%	8	3
Point detector HVPS #2 setting		D	As commanded		9	2
Point detector HVPS #2 reading		A	TBD	1%	8	3
Point detector 1X deflection setting		D			7	
Point detector 1X deflection reading		A			8	
Point detector 1Y deflection setting		D			7	
Point detector 1Y deflection reading		A			8	
Point detector 2X deflection setting		D			7	
Point detector 2X deflection reading		A			8	
Point detector 2Y deflection setting		D			7	
Point detector 2Y deflection reading		A			8	
ICCD detector HVPS setting		D	As commanded		1	2
ICCD detector HVPS reading		D	TBD	1%	8	
ICCD gate sync setting		D	As commanded		8	

- *1 - Operational Data
- 2 - Header Data
- 3 - Engineering Data



Table IV-3 (Continued)
INSTRUMENTATION LIST - HSP/AP

Signal	Description	Signal Type	Range	Analog Accuracy	Number Of Bits	*Data Type
	ICCD gate sync reading	A	TBD	1%	8	
	ICCD cooler	D	On/Off		1	
	ICCD cooler current setting	D	TBD	1%	8	
	ICCD cooler current reading	A	TBD	1%	8	
	ICCD detector temperature reading	A	TBD	1%	8	
	LVPS voltages (6 x 8 bits)	A	TBD	1%	48	
	LVPS currents (6 x 8 bits)	A	TBD	1%	48	
	Reserve for final design definition 10-20%					
	Reserve for diagnostics 20-25%					
	(Requirements for the reserves are currently being developed)					



- *1 - Operational Data
- 2 - Header Data
- 3 - Engineering Data

Table IV-4
COMMAND SEQUENCE - HSP/AP

Sequence	Function
Thermal Control	Bring instrument on-line to thermal operating temperature.
Standby	Low voltage P.S. to on - instrumentation system on-command system on.
Acquisition Initialize	Set variables (mechanisms, power supply voltage, exposure time, mode select).
Acquisition Execute	Expose, record, readout, standby.
Calibrate Initialize	Set variables (mechanisms, power supply voltages, exposure time, mode select)
Calibrate Execute	Expose, readout, record - precalibrate initialize report approximately 350 cycles for total calibration. NOTE: Fewer than 350 cycles now required since polarimetry function deleted.
Operate Initialize	Set variables (mechanisms, power supply voltages, exposure time, mode select).
Operate Execute	Expose, readout, record - standby or off.





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Table IV-5 shows the various HSP/AP command functions and digital bit requirement for each function.

Table IV-5
COMMAND REQUIREMENTS - HSP/AP

Command	Steps	Bits/ Variable Word	Discrete Commands
Thermal Control			
Thermal Control HSP/AP On			1
Thermal Control HSP/AP Off			1
Standby			
HSP/AP Standby On			1
HSP/AP Standby Off			1
Acquisition Initialize			
Aperture Wheel Position	10	4	
Filter Wheel Position	10	4	
Mode Selector	5	3	
HVPS - Area Detector	512	9	
Exposure Time	1 millisec to 10 hours	26	
Load (One for Each Variable Command)			6
Execute (One for Each Variable Command)			6
Acquisition Execute			
Acquisition Start			1
FCS Bias	262, 144x2	18 Bits Each	
Read Start			1



Table IV-5 (Continued)
COMMAND REQUIREMENTS - HSP/AP

Command	Steps	Bits/ Variable Word	Discrete Commands
Acquisition Execute (Continued)			
Read Stop			1
Load (One for Each Variable Command)			1
Execute (One for Each Variable Command)			1
Calibrate Initialize			
Aperture Wheel Position	10	4	
Filter Wheel Position	10	4	
Mode Selector	5	3	
Area Detector HVPS	512	9	
Point Detector HVPS 1	512	9	
Point Detector HVPS 2	512	9	
Exposure Time	Millisec to 10 hours	26	
Load (One for Each Variable Command)			9
Execute (One for Each Variable Command)			9
Calibrate Execute			
HSP/AP Calibration Start			1
Read Start			1
Read Stop			1
Exposure Interrupt			1
Exposure Restart			1



Table IV-5 (Continued)
COMMAND REQUIREMENTS - HSP/AP

Command	Steps	Bits/ Variable Word	Discrete Commands
Operate Initialize			
Aperture Wheel Position	10	4	
Filter Wheel Position	10	4	
Mode Selector	5	3	
HVPS	512	9	
Exposure Time	Millisec to 10 hours	26	
Load (One for Each Variable Command)			6
Execute (One for Each Variable Command)			6
Operate Execute			
HSP/AP Operate			1
Read Start			1
Read Stop			1
Exposure Interrupt			1
Exposure Restart			1





Section 5 CONTAMINATION CONTROL

The major concerns for the HSP/AP relating to potential contamination and the attendant degradation of performance are discussed below. Some suggested approaches based on successful control programs for UV instruments similar to those on ST, such as those in the Skylab Apollo Telescope Mount, are discussed.

- The HSP/AP is threatened by the absorption and scatter of condensed contaminants, especially because of its very high sensitivity, resolving power and resolution and its long lifetime. The ultraviolet wavelength region is particularly sensitive to contamination.
- Cooled detector surfaces will collect outgassed molecules (including the lighter molecules that do not condense at room temperature) much more efficiently than will nearby warmer surfaces, thereby increasing the contaminant threat to the area detector.
- The optical path is folded, increasing the number of interactions of the optical beam with potentially contaminated surfaces.
- The instrument contains moving elements that can introduce lubrication problems if appropriate lubricants and precautions are not implemented. Long life implies wet lubrication, but wet lubrication represents a condensable contamination threat. Dry lubricants generally exhibit shorter lifetimes and represent particulate contaminant threats. BBRC's Vac Kote dry lubricant is a space proven clean lubricant for this application.



- Contamination control will involve very careful material and process selection and handling and storage procedures. At the present time, it appears that materials being used in highly critical areas (near UV optical elements, etc.) would be selected under the same criteria used successfully for the ATM UV instruments, namely, that under the given test conditions the reflectance changes produced by the materials would be $\Delta R/R < 5\%$, where ΔR = the reflectance and R = the original reflectance of the mirror.
- Contamination control will also involve configuration control and baffling to remove sources of contaminants (electronics, moving parts, etc.) as far from susceptible critical elements as possible. It may also include continuous pressurization with clean, filtered gas during ground test, integration, storage and transport.
- Control will also include monitoring of the instrument environment (especially in the UV region) during handling and testing. This will involve mass spectrometric and UV reflectance monitoring techniques used on the ATM instruments and quite possible will involve the use of NRL's Real-Time Contamination Monitor and/or MSFC's Laser Monitor. It will also require the usual monitoring techniques for particulates.
- In order to maintain satisfactory cleanliness, appropriate cleaning using approved solvent washes and wipes, bakeouts, vacuum cleaning, etc., will be required as initial clean-up on the instrument prior to installation of optics. Subsequent cleaning will require close supervision and conformance to approved procedures.



The HSP/AP contamination control requirements and control techniques are the same as those required on many previous UV type space instruments. The material and process control procedures, optics procedures, test procedures, etc, exist as in-house BBRC documents directly applicable to the High Speed Point/Area Photometer.



Section 6 RELIABILITY

We recommend that the reliability program for the High Speed Point/Area Photometer (HSP/AP) be conducted in accordance with the reliability assurance requirements for the Apollo Applications Program as outlined in NASA document NHB5300.5 with amendments for the ST program. This requirement should be applicable to the HSP/AP including parts, subassemblies, and modules throughout the end-item phases of the program.

(a) Reliability

The preliminary minimum reliability goal of the HSP/AP is 0.85 for the first year of operation of the ST. The HSP/AP shall also be designed to operate for at least two years before maintenance action occurs (degraded reliability permitted after the first year).

The reliability of the photometer will be verified by analytical analysis using applicable government and industry recognized failure rates such as those of RADC Reliability Notebook TR67-108 Vol. II or MIL-HDBK-217. Other failure rates/sources must be substantiated for the ST mission requirement. Dormant (non-operating) failure rates for electronic parts shall be the customary 10 percent of the active failure rate. Thermal and electrical stresses should be representative of the actual stresses and can be measured, calculated and/or estimated.

(b) Operating Life

The HSP/AP requires a total operating life of 17,520 hours (prior to earth return for refurbishment/modification) when serviced by replacement of modules and parts. This operating life includes all on-orbit time periods (dormant, warm-up, standby and active) but excludes storage time of the photometer and component parts.



(c) Single Point Failures

The HSP/AP will have no single point failure items which, if failed, would lead directly to the loss of a crew member, the primary ST mission, or a primary mission objective.

(d) Life Limited Items

Limited life items (detectors, motors, and mechanisms) will have a useful life which will assure proper operation of the devices from one preventive maintenance action until the next. As a goal, the detector must survive for 4,000 on-orbit operating hours with no greater than 10 percent degradation of the critical parameters. The detector must also be capable of surviving another 6,000 hours of dormant, warm-up and standby time. Motors and mechanisms must survive for 20,000 operating hours when cycled in accordance with the predicted average cyclic rate for the devices.

(e) HSP/AP On-Orbit Mission Profile

The HSP/AP on-orbit mission profile is restricted only by the scientific instruments operating schedule. The photometer contains three detectors which can be energized simultaneously, singly or in any combination. However only one detector at a time can be in the optical path and therefore can collect data. The most common operation assumed for the reliability analysis is to use the area photometer to perform acquisition verification and then to switch to the high speed point detectors to perform scientific data collection. The high speed point detectors collect data in slightly different wavelengths but can be switched from detector to detector for broad wavelength coverage and comparison purposes. Operation of the area detector and either of the high speed point detectors is assumed as the required criterion for the HSP/AP mission success. The on-orbit photometer



operating time is presently estimated at 20 percent of the available scientific time.

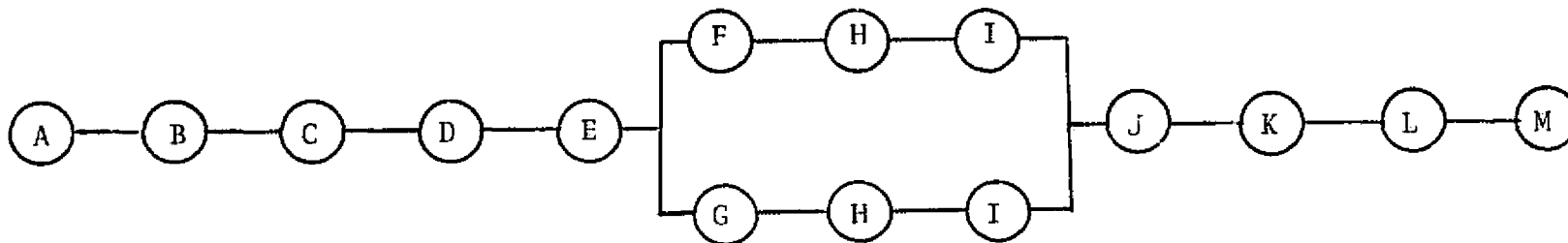
(f) Electrical/Electronic Parts

We recommend part selections be from GSFC and MSFC preferred parts lists (PPL). Other parts should be selected from the best available established reliability (ER) parts, JAN-TX or JAN-TXV semiconductors and integrated circuits processed to product assurance level A of MIL-STD-883. Nonstandard parts require equivalent screening levels as those established for the ER, JAN and MIL-STD-833 parts. Parts will be electrically and thermally derated to the extent required to meet the reliability MTBF requirement. The GSFC PPL contains appropriate derating criteria.

(g) HSP/AP Reliability Model

The reliability model for the HSP/AP is shown in Figure 6-1. The model indicates that the area detector and one of two high speed point detectors is required for photometer success. Operation of the 4 position mode selector (switching mirrors) is required to switch from area detector to high speed point detectors IDS 1 or IDS 2.

The critical items which would cause the loss of the instrument if any one failed catastrophically are the aperture wheel, the filter wheels, the mode selector and mirrors, the relay optics, the area detector and electronics, the area detector cooler, and data memory electronics, and the TLM header sensors and electronics. No fail-safe considerations are included in this analysis. The area detector cooler is a thermoelectric cooling unit and therefore is not operating time limited.



KEY

- A 10 position field stop wheel, motor and drive electronics
- B 10 position filter wheel 1, motor and drive electronics
- C 10 position filter wheel 2, motor and drive electronics
- D 4 position mode selector, motor and drive electronics
- E Relay mirror, switching & hyperboloid mirror
- F Point detector IDS 1 and electronics
- G Point detector IDS 2 and electronics
- H High voltage supply
- I Detector memory
- J Area detector and electronics
- K ICCD cooler
- L Detector memory
- M TLM header data for data frame housekeeping data (non-critical)

Figure 6-1 HSP/AP Reliability Model



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(h) System Reliability Calculation

For analysis purposes it was estimated that the HSP/AP will be operated at 20 percent of the on-orbit operating hours which gives a failure rate modification factor of 0.1900. The HSP/AP reliability for one year is then calculated as shown in Table VI-1.

Table VI-1
HSP/AP INSTRUMENT DUTY CYCLE
FAILURE RATE & RELIABILITY CALCULATIONS

<u>Subsystem</u>	<u>FR x 10⁻⁹/hr</u>	<u>Mod Factor</u>	<u>Duty Cycle FR</u>
Aperture Wheel	1500	.190	285
Filter Wheels (2)	3000	.190	570
Mode Selector	1500	.190	285
Optical Elements (5)	1000	.190	190
IDS Detector & Elec.	19625*	.190	548
IDS Detector & Elec.	19625		
Area Detector & Elec. & Cooler	21625	.190	4109
Common Electronics	3750	.190	<u>713</u>
Total λ			6700 x 10 ⁻⁹

* Active redundant - equivalent failure rate for one year =
2884 x 10⁻⁹

$$R = e^{-\lambda t} \text{ where: } \lambda = 6700 \times 10^{-9}/\text{hr} \text{ \& } t = 8760$$

$$R = 0.943 \text{ for 1 year}$$



Section 7

GROUND SUPPORT EQUIPMENT

The GSE list and requirements discussed concern the total needs of the HSP/AP. It is assumed that the sophisticated GSE will be supplied as part of the SI Command and Data Handling system and the instrument contractor will only supply a minimal functional check-out system.

The Ground Support Equipment (GSE) needed to support the instrument will consist of the following:

A. ELECTRICAL

1. S/C Simulator
2. Tape Recorder
3. Minicomputer
4. Computer Operator Console
5. Line Printer
6. Memory Disc
7. Display Devices

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OF POOR QUALITY

The spacecraft simulator would provide all of the functions required from the spacecraft to operate the HSP/AP. These would include commands, timing pulses, clock, A/D converter, telemetry system, etc.

The tape recorder will be used as a storage device to record data during testing and calibration. The data can be saved for future reference or played back to the computer for processing.

The minicomputer and memory disc will be utilized for data reduction and controlling HSP/AP automatic operations. The line printer will be for the output of various forms of data and parameters as desired.

The display devices will consist of a TV monitor with a refresh memory and a hard copy printer.



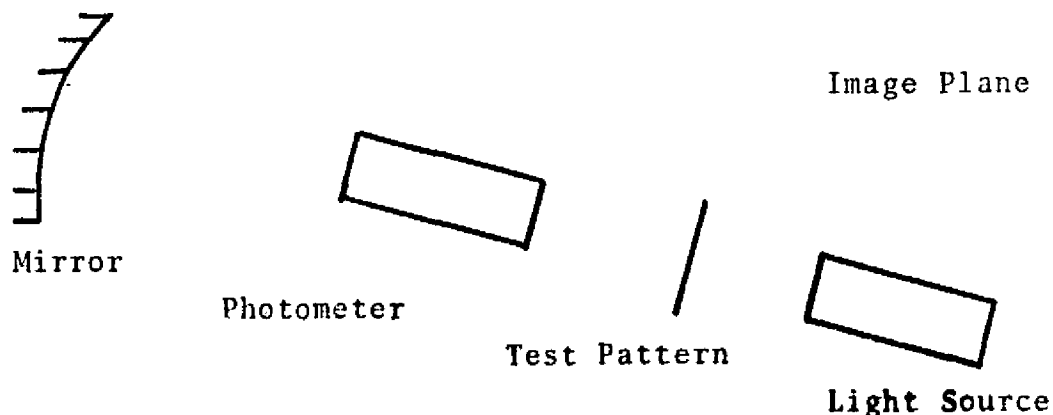
The GSE would be utilized for testing the instrument throughout the program up to spacecraft integration. The equipment would remain on a standby basis after spacecraft integration for such cases as troubleshooting, special testing and any other unforeseen events that may require its use.

The following are estimated sizes and weights of the electrical support equipment.

1.	S/C Simulator, Computer, Display Devices	TBD
2.	Tape Recorder, Memory Disc	TBD
3.	Operator Console (Type-writer)	TBD
4.	Line Printer	TBD

B. OPTICAL TEST EQUIPMENT

1. Optical Projector



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This projector will provide a high resolution image at the entrance aperture to the HSP/AP. The light source will be an interchangeable assembly capable of covering the spectral response of the HSP/AP. The projector will be a vacuum compatible unit. A number of metal test patterns will be supplied consisting of clear aperture, two-axis resolution patterns and single-axis bar patterns.

The output from the light source will be monitored by a photon counting photometer inserted into the light path by remote control. The intensity from the source will be controlled over a wide dynamic range 1000:1.

Size:	2 m long x 45 cm diameter	Weight:	100 kg
	(50.8 in) (17.7 in)		(220 lb)

2. Collimator

A similar system is required for projecting a high resolution image into the ST after installation of the HSP/AP into the OTA. It is assumed that a suitable collimator will be available with provision for mounting the HSP/AP projection system. It is conceivable that the above projector could be used for both applications.

3. Miscellaneous Equipment

Monochromator--115 nm to 650 nm range

Auto Collimator

Laser

Optical Flat, Beam Splitter, etc.



C. HANDLING EQUIPMENT

	<u>Dimensions</u>	<u>Weight</u>
1. Shipping Container	TBD	TBD
2. Horizontal Lifting Fixture	(chains & spreader bar)	TBD
3. Vertical Lifting Fixture	(chains & spreader bar)	TBD
4. Container Lifting Fixture	(chains & spreader bar)	TBD

The shipping container is assumed to be similar to the types used to ship the AIM instruments. The container provides a sealed atmosphere of dry nitrogen gas during shipment or storage for the HSP/AP instrument. Instrumentation in the container monitors temperature, humidity and vibration shocks. The instrument is mounted to a fixture which is shock-mounted to the container base. Wheels and lift lugs facilitate container handling. The lifting fixtures are utilized with an overhead crane. The fixtures attach to hard points on the container, container cover and the instrument.



Section 8 INTEGRATION AND TEST

8.1 TESTING

The High Speed Point/Area Photometer will be qualified and acceptance tested as a subsystem prior to its integration into the OTA. This testing will follow the plan defined in GSFC Report No. X-604-74-290, GSFC Integration, Test and Evaluation plan for ST Focal plane Assembly. Major components and subassemblies will undergo development testing as required to support the detailed design. Such testing will include breadboard testing of electronic circuits, temporal stability measurements of calibration sources and sensitivity/uniformity measurements of detector photocathodes.

Subsystem Testing

Mechanical

Stepper motors will be tested for speed, torque and angular position repeatability. The field stop wheel assembly, filter wheel assemblies and switching mirror assembly will be tested for position repeatability, function and friction levels.

Optical

The HSP/AP optical elements include mirrors and filters. All mirrors are checked for figure, surface condition, reflectance and dimensions. Filters will require tests to verify through-put characteristics.



Electronic

All electronic subsystems will be functionally tested. This will include the following:

- Switching mirror drive
- TLM control logic
- Low voltage power supply
- High voltage power supply
- Instrument control and command logic
- Filter stop wheel drive
- Filter wheel drives

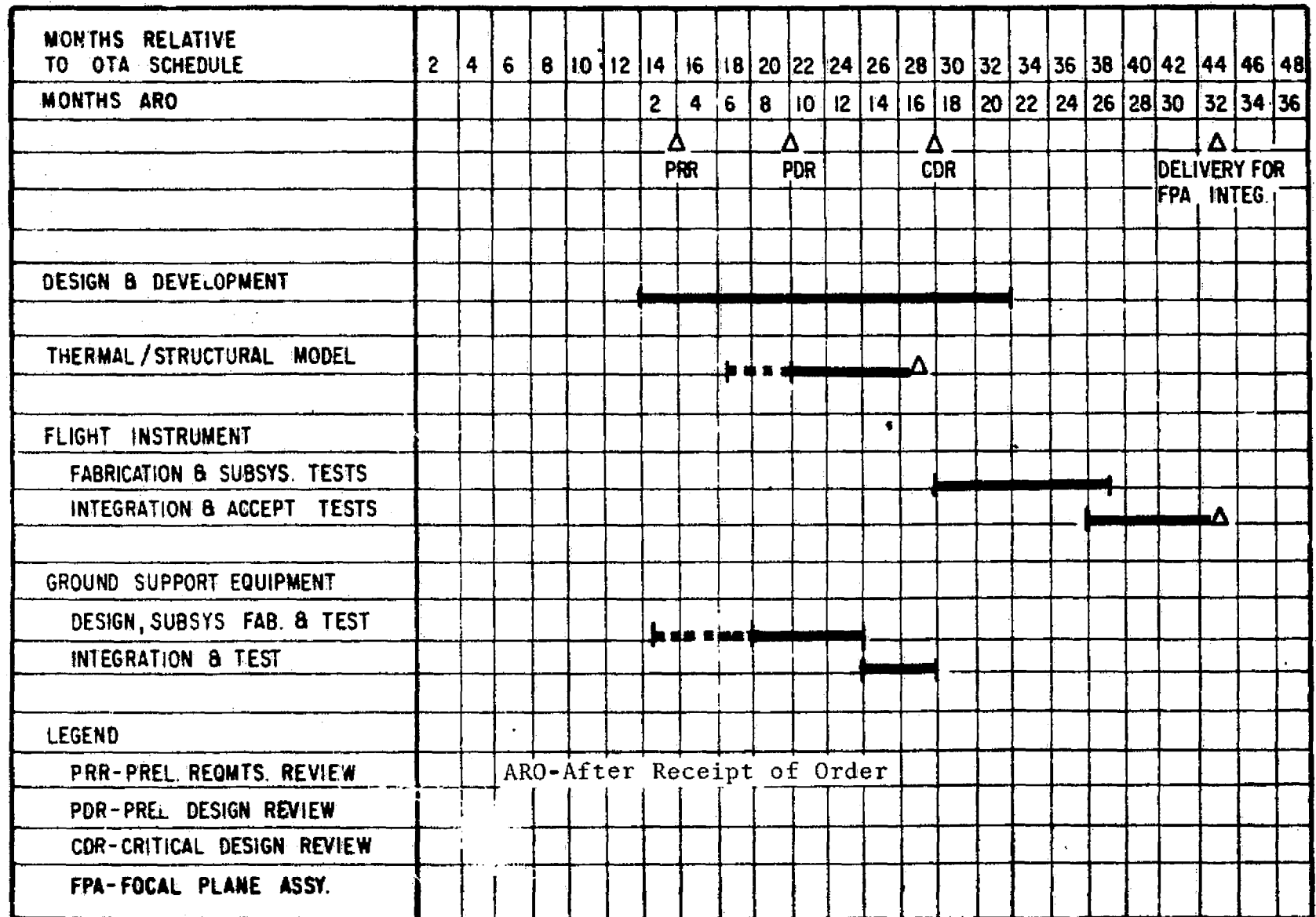
System Testing

The integrated HSP/AP will be functionally tested before and after EMI, vibration and thermal/vacuum environments are imposed. These tests will verify instrument electronics and mechanical performance. Additional optical tests will be conducted to measure instrument spectral and spatial resolution, throughput and photometric uniformity. Thermal/vacuum testing will be conducted at ambient temperature, +95F and +40F. Functional testing will utilize a vacuum light source or sources as inputs to the HSP/AP having a spectral range from 115 to 650 nm.

8.2 QUALIFICATION AND INTEGRATION WITH OTA

As noted in Section 8.1 qualification testing will be conducted at GSFC. Figure 8-1 gives the schedule of key milestones for the instrument design, assembly, and testing as well as its delivery to the OTA contractor for integration. The instrument contractor will provide thermal/structural model (T/SM) to GSFC. GSFC will integrate this model with a focal plane structure (FPS) provided by the OTA contractor. This FPS will be, as far as

8-5



10/20/00

F76-08

Figure 8-1 High Speed Point/Area Photometer Development Structure



possible, a duplicate of the FPS being designed for the OTA. GSFC will integrate the TSM into the FPS and conduct a series of tests of this assembly to verify the thermal/structural design of the HSP/AP. This testing information will be input to the continuing design of the instrument.

The completed flight instrument will be delivered to GSFC at month 44 of the program. GSFC will integrate it (along with the other SI's) into the FPS and conduct the tests defined in Report No. X-604-74-290. This testing program will qualify the individual instruments. At the conclusion of this test sequence the SI's will be certified as accepted flight instruments for delivery to OTA integration. The SI contractor will participate in and support the testing program at GSFC.

Figure 8-2 defines the schedule for the integration of the HSP/AP (and all other SI's) into the OTA. Months 60 and 61 are provided for the receiving and inspection at the OTA integration site. Following acceptance it will be integrated into the OTA by the OTA contractor. The tests defined in Table 8-1 will be conducted on the OTA/SI assembly during the period months 62-68.

Figure 8-3 illustrates the interface conformation sequence for the development/integration of the science instruments. MSFC, as prime contractor, will accept the SI enclosures provided by the OTA contractor. They will be supplied to GSFC which will accept/forward the enclosures to the individual contractors. The completed instrument will go to GSFC for environmental/qualification tests as described, and will be accepted by MSFC prior to integration into the OTA.

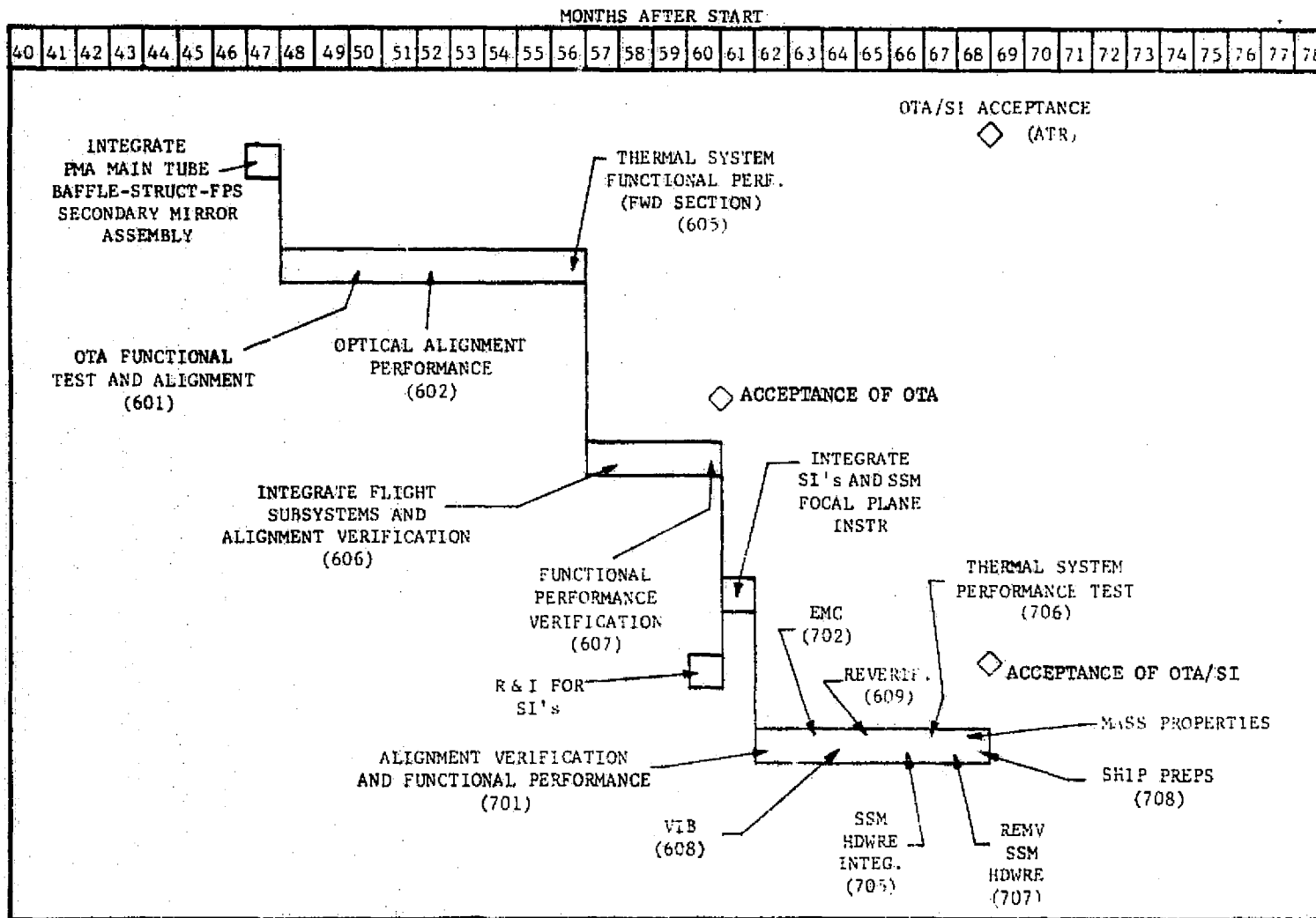


Figure 8-2 OTA and OTA/SI Test Sequence

Table 8-1 TESTING OF HRS

Test #	Title	Testing/Special Test Equip.
701	Alignment Verification and Functional Performance	The OTA with all science instruments installed will be installed in a thermal/vac test chamber as shown in Fig. 8-6. Using the 72" collimator as shown in Fig. 8-7, the SI's will be verified for alignment and function.
702	EMC	Limited EMC testing will be conducted during Test 701. Test will be limited to monitoring of busses and critical signal lines.
608	Vibration	OTA/SI assembly removed from chamber, subjected to acceptance level vibration.
609	Re-verification of Functional Performance	Return OTA/SI to test chamber and repeat Test 701 to insure system functional after the vibration test.
705	Integration of SSM Hardware	Install SSM Flight Forward Shroud, simulated SSM section and SSM Flight Aft Shroud.
706	Thermal System Performance Test	<p>Test to verify the <u>Optical Performance</u> of OTA/SI under simulated thermal environment. Also to verify thermal interface between SSM and OTA/SI. This includes stability of optical metering truss and power dissipation from the SI area. The test will also verify SI power requirements.</p> <p>Test will be conducted with OTA/SI vertical in test chamber, with 72" collimator input and with thermal simulation of space environment as shown in Fig. 8-6.</p>
707	Removal of SSM Hardware	Following test 706, the SSM Flight hardware is removed.
708	Mass Properties Verification	Verification of Flight OTA/SI.

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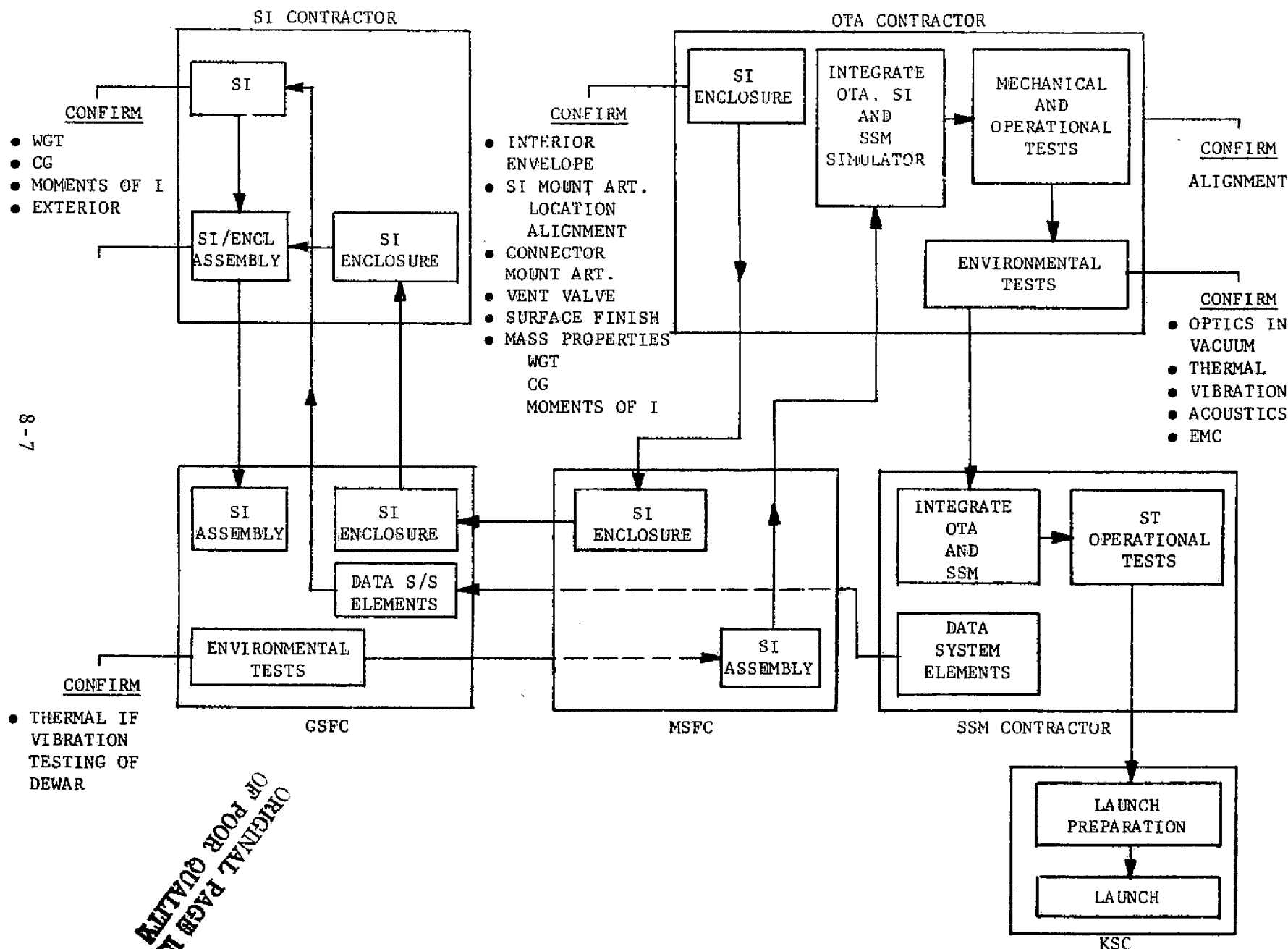


Figure 8-3 OTA/SI Interface Confirmation

ORIGINAL PAGE IS
OF POOR QUALITY

8.3 ENVIRONMENTAL CONTROL

Figures 8-4 and 8-5 define the environmental conditions which are required during all ground handling assembly, testing, refurbishment and transportation. The importance of the HSP/AP to successful ST performance demands a highly reliable design. Because of the long period of ground integration and test and the degrading effect of contamination on performance in the UV it is critical that high levels of cleanliness and careful control of temperature and humidity be maintained. As integration moves to a higher level and ST system size makes such control more difficult, special effort will be required to provide and use covers to protect the HSP/AP when not undergoing actual test or checkout.

<u>Environmental Parameter</u>	<u>Limits</u>	<u>Max Rate of Change</u>	<u>Remarks</u>
Air Temperature, Ambient Dry Bulb	65°F to 78°F	20°F/Hr	
SI Equipment Temperature	65°F to 78°F	10°F/Hr	For operational require- ments, see Paragraph 3.5.6.
Relative Humidity Ambient Air	< 50%	N/A	Note A.
Cleanliness SI/SI Encl. Integ.	10,000 Max.	N/A	
Ambient Air OTA/SI Integ.	10,000 Max.	N/A	Fed Std. 209 - See Note B
SSM Integ.	10,000 Max.	N/A	
Cleanliness SI	Class 200, Level B	N/A	
Cleanliness SI Enclosure Viewing the SI	MIL-STD-1246A	N/A	At the time of integration of the SI with the SI enclosure.

NOTES:

- A. During thermal vacuum testing, repressurization shall be controlled to prevent any condensation on OTA/SI surfaces or particulate matter back-stream.
- B. During OTA/SI to SSM integration, operations which would expose the interior of the OTA/SI to the ambient environment shall be performed in a Class 10 K environment. Operations which do not expose the OTA/SI interior to the ambient environment may be performed in a Class 100K environment. Appropriate seals and closures on the OTA/SI or plastic tents supplied by HEPA filtered blowers shall be considered as meeting the intent of this requirement.

Figure 8-4 General Environments for the SI Within the SI Enclosure
(Handling, Including Factory, Refurbishment)

<u>Environmental Parameter</u>	<u>Limits</u>	<u>Rate of Change - Max</u>	<u>Remarks</u>
Air Temperature, Ambient Dry Bulb	50°F to 90°F	20°F/Hr	
Relative Humidity	< 50%	N/A	Note A
Cleanliness - Conditioned Air	100,000		Fed Std 209 - Note B

NOTES:

- A. No condensation shall be allowed on any exposed surface of OTA/SI equipment at any time.
- B. During transportation, interior of OTA/SI to be closed off to maintain class 10K environment internally while exposed to class 100K environment externally.

Figure 8-5 . Transportation

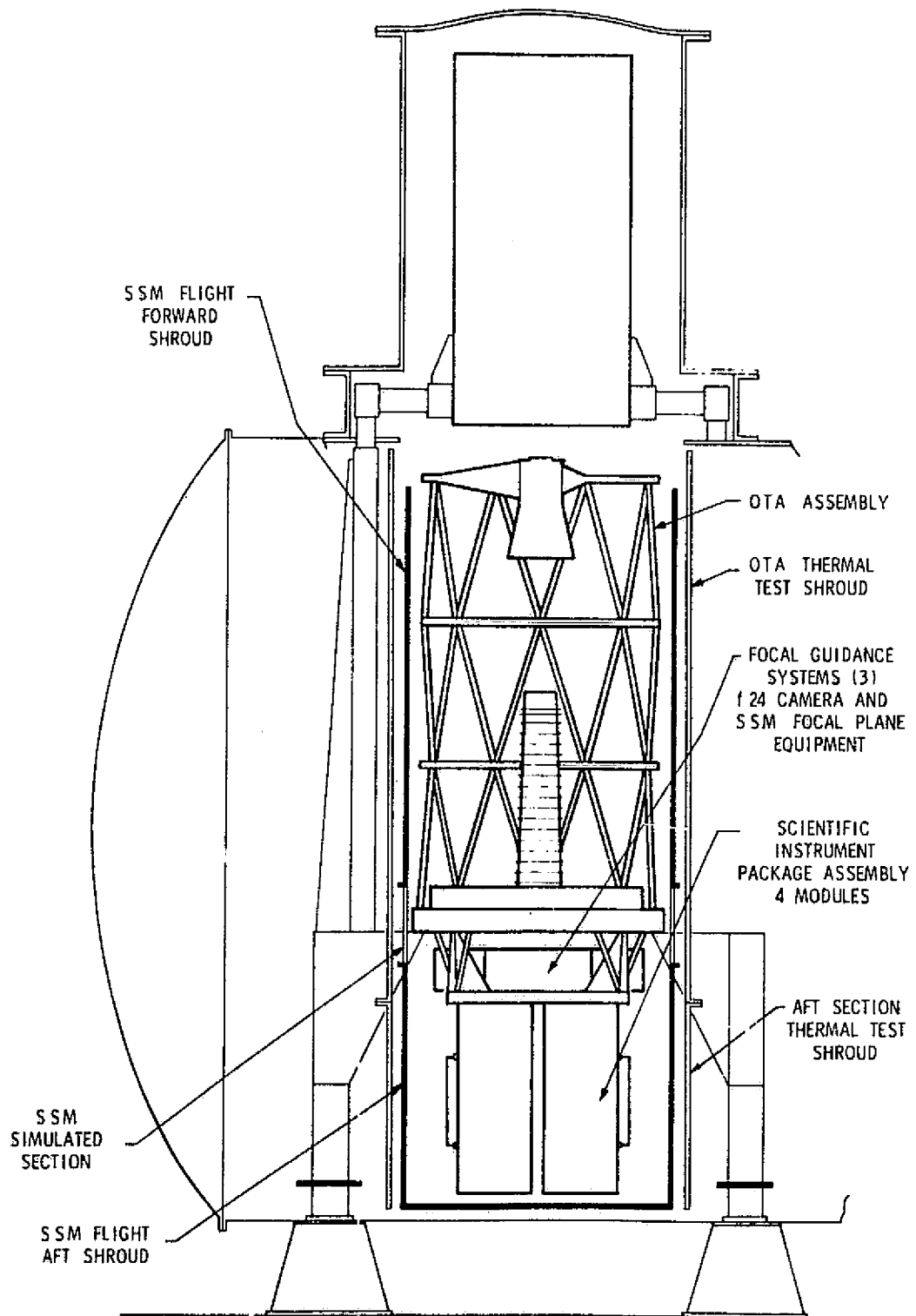


Figure 8-6 OTA/SI Thermal System Performance Test

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72" PARABOLA-TOLERANCE
 $\lambda/20$ KNOWN TO $\lambda/77.8$

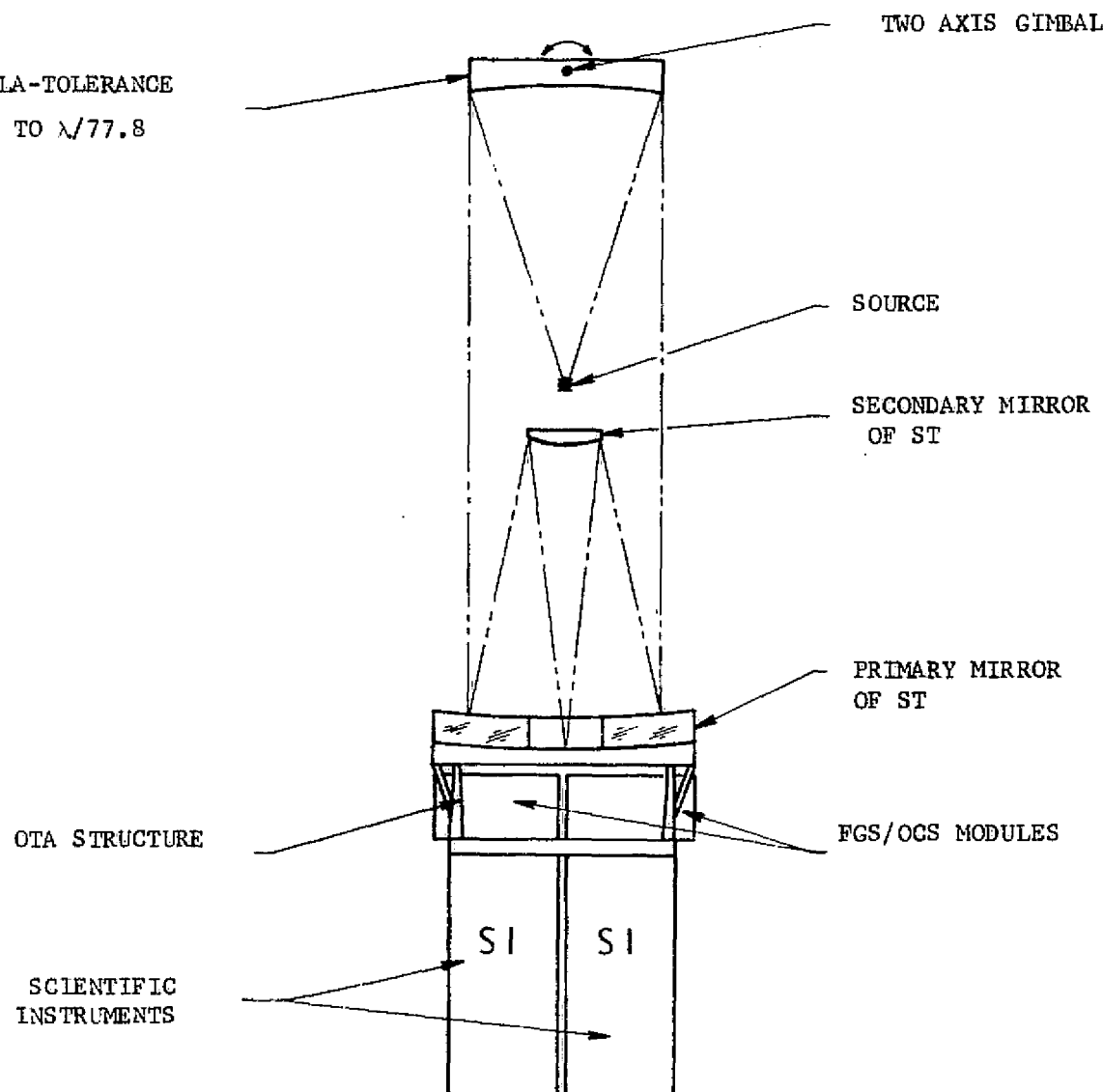
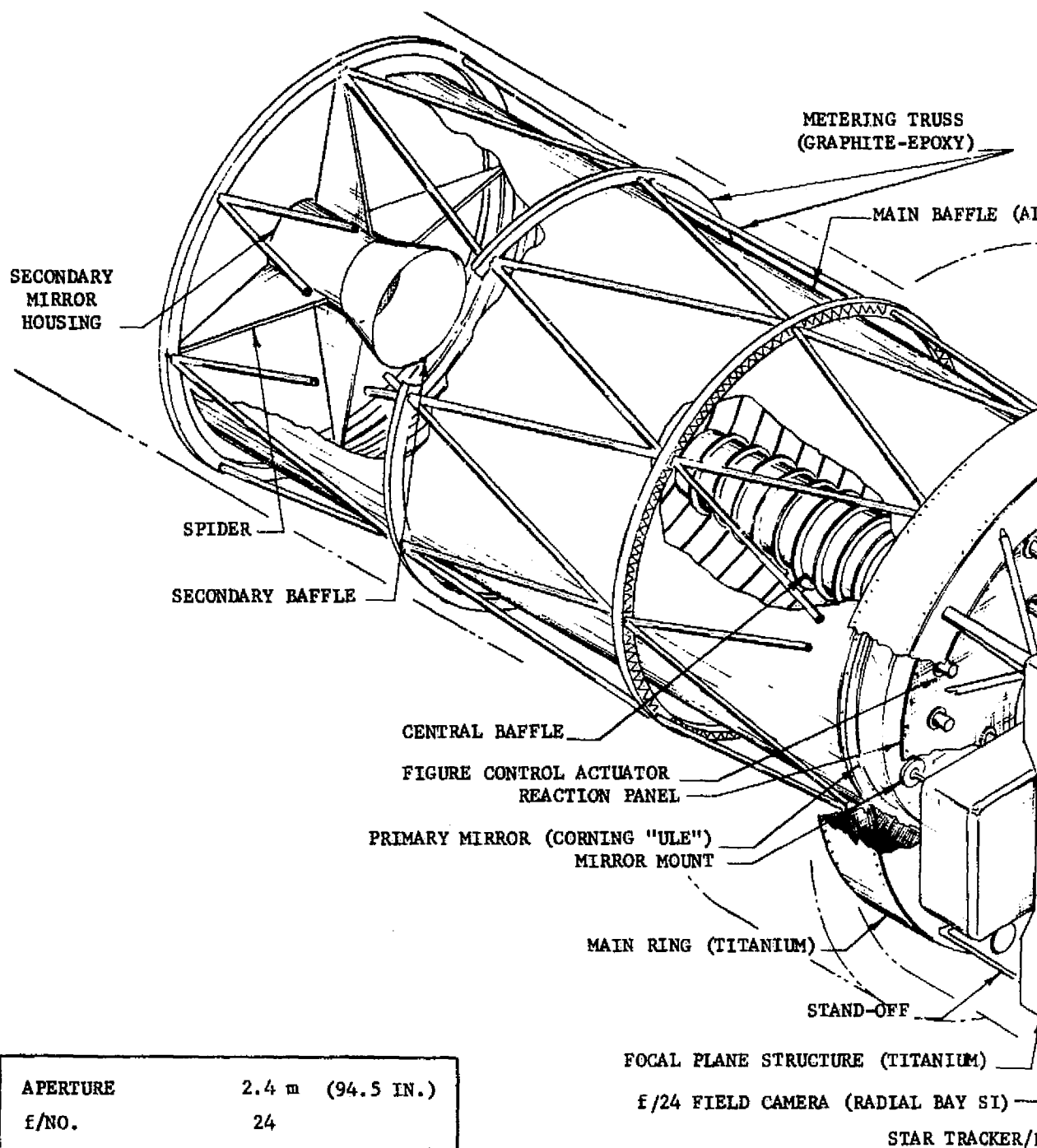


Figure 8-7 72" Collimator System Test Configuration



APERTURE	2.4 m	(94.5 IN.)
f/NO.	24	
OVERALL LENGTH	8.8 m	(347 IN.)
MAXIMUM DIAMETER	3 m	(118 IN.)
WEIGHT	2570 Kg	(5665 LB)

G TRUSS
(E-EPOXY)

MAIN BAFFLE (ALUMINUM)

SSM (REFERENCE)

SSM ATTACHMENT FITTING
(3 @ 120°)

FINE GUIDANCE SENSOR/
WAVEFRONT SENSOR MODULE
(3 @ 90°)

AXIAL SCIENCE
INSTRUMENT

CRUCIFORM PANEL

STABILIZER
TRUSS

LATCH
MECHANISM

OFF

(TITANIUM)

DIAL RAY SI)

STAR TRACKER/RATE GYRO SHELF

INSTRUMENT LATCH HANDLE

CONNECTOR
LOCATION

NASA-MSFC-C

Optical Telescope Assembly
With Science Instruments

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FOLDOUT FRAME²